DOCUMENT RESUME

ED 153 040 CE 015 687

AUTHOR Prophet, Wallace W.
TITLE Long-Term Retention of Flying Skills: A Review of the Literature. Final Report 76-35.
INSTITUTION Human Resources Research Organization, Alexandria, Va.
SPONS AGENCY Air Force, Washington, D.C.
REPORT NO FR-ED(P)-76-35
PUB DATE Oct 76
CONTRACT F44620-76-C-0106
NOTE 95p.

EDRS PRICE MF-$0.83 HC-$4.67 Plus Postage.
DESCRIPTORS *Aircraft Pilots; *Armed Forces; Behavioral Science Research; *Flight Training; Job Skills; Literature Reviews; Memory; Military Training; Personnel Management; *Psychomotor Skills; Research Needs; Research Reviews (Publications); *Retention; Surveys
IDENTIFIERS *Air Force; United States

ABSTRACT

This is a survey of the state of behavioral science knowledge related to long-term retention of flying skills completed for the U.S. Air Force (USAF). The report contains a survey of selected agencies and knowledgeable individuals as well as a literature review. (A list of libraries, agencies, and individuals consulted is appended, but a complete annotated bibliography was published separately.) The results of the review suggest that basic flight skills can be retained fairly well for extended periods of nonflying, but some decrement of concern does occur, particularly for instrument and procedural skills. Retraining of basic flying skills is judged not to be a major USAF problem, and much of the proficiency maintenance/retraining requirements can be met through the use of training devices and simulators. However, it is suggested that little is known about the retention, maintenance, and retraining of higher level pilot skills that characterize the USAF pilot in tactical units. Thus, recommendations are made for areas of further research that would help in the establishment of manpower management policies for the USAF pilot force. (BB)

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Final Report
76-35

HumRRO
FR-ED(P)-76-35

HumRRO

ED153040

Long-Term Retention of Flying Skills:

A Review of the Literature

by

Wallace W. Prophet

HUMAN RESOURCES RESEARCH ORGANIZATION
300 North Washington Street • Alexandria, Virginia 22314

The contents of this report do not necessarily represent the official opinion or policy of the U.S. Air Force.

October 1976

Prepared for:

Assistant Chief of Staff, Studies and Analysis
Hq., United States Air Force
Washington, D.C. 20330

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CE 015 687

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: FR-ED(P)-76-35	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): LONG-TERM RETENTION OF FLYING SKILLS: A REVIEW OF THE LITERATURE	5. TYPE OF REPORT & PERIOD COVERED: Final Report, May 1976 - October 1976
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Wallace W. Prophet	8. CONTRACT OR GRANT NUMBER(s): F44620-76-C-0106
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Human Resources Research Organization, 300 North Washington Street, Alexandria, VA 22314	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: Headquarters, USAF, Assistant Chief of Staff, Studies and Analysis, AF/SAA, Washington, D.C. 21332	12. REPORT DATE: October 1976
	13. NUMBER OF PAGES: 87
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWN-GRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Retention	Memory	Retraining flight skills
Flying skills	Proficiency flying	Manpower management
Proficiency maintenance	Combat readiness training	Rated supplement flying
Skills maintenance	Continuation training	
Forgetting	Recurrency training	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In support of USAF Saber Wings II study, a survey of the state of behavioral science knowledge with reference to long-term retention of flying skills was conducted. Various literature sources were surveyed, as well as selected agencies and knowledgeable individuals. Results of the review suggest that basic flight skills can be retained fairly well for extended periods of non-flying, but some decrement of concern does occur, particularly for instrument and procedural skills. Retraining of basic flying skills is judged not to be

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

a major USAF problem, and much of the proficiency maintenance/retraining requirements can be met through the use of training devices and simulators. The review suggests, however, that little is known about the retention, maintenance, and retraining of higher level pilot skills that characterize the professional USAF pilot in tactical units. It is retention and retraining of these higher level skills that is the major concern in establishing manpower management policies with reference to USAF rated supplement pilots. Literature dealing with the nature of these higher level pilot skills is discussed. Conclusions are drawn with reference to flight skills maintenance and retraining, and with reference to management of the rated force. In addition, areas in need of additional research are identified. It is concluded that the general state of knowledge is inadequate to USAF current and future needs and that a better base of data on which to develop policies is needed.

CONTENTS

Chapter		Page
I.	BACKGROUND AND PROBLEM	1
	Introduction	1
	Background	2
	USAF Training and Skill Retention	4
	Saber Wings II	6
II.	STUDY OBJECTIVE AND METHOD	10
	Objective	10
	Method	10
	Literature Survey	10
	Agency Survey	11
	Survey of Individuals	12
	General Scope of Survey	13
III.	RESULTS	14
	The Nature of Flying Skills	14
	Prior Research	14
	Phases of Skill Acquisition	15
	Research on Abilities and Skills	16
	The Pilot as Information Processor	18
	Combat Readiness	20
	Organization of Literature Review	22
	General Comments on the Literature	23
	Previous Literature Reviews	28
	Naylor and Briggs Review	30
	Gardlin and Sitterley Review	31
	Other Literature Reviews	33
	Flight Skill Retention Studies	36
	Air University and Naval Postgraduate School Studies	36
	Military/NASA Retention Studies	38
	FAA Retention Studies	49
	Airline Retention Studies	50
IV.	DISCUSSION AND IMPLICATIONS	54
	General Retention Factors	55
	Level of Learning	55
	Length of Retention Interval	56
	Habit Interference and Transfer	60
	Rehearsal Effects	61
	Task/Skill Factors	62
	Control and Procedural Tasks	62
	Instrument and Contact Tasks	64
	Information Processing Tasks	64
	Other Task Factors	65
	Retraining Factors	66
	Use of Devices	66
	Nature of Training	67
	Individual Factors in Retraining	68

CONTENTS - Continued

Chapter		Page
V.	CONCLUSIONS	73
	Flight Skills Maintenance/Retraining	74
	Management of the Rated Force	75
	Research Needs	76
	BIBLIOGRAPHY	81
	APPENDIX: Listing of Libraries, Agencies, and Individuals Consulted	86

LIST OF TABLES

Table		Page
1.	Publications Reviewed - By Year of Publication	26
2.	Commonality of Three Literature Reviews	27

FOREWORD

This report presents results of a survey of the behavioral science literature dealing with the subject of long-term retention of flight skills. The effort was performed for the Office of the Assistant Chief of Staff, Studies and Analysis, Hq., United States Air Force, in support of their studies of pilot proficiency and management of the rated force (SABER WINGS II). The literature survey results are presented here in an interpretive commentary which relates the literature to areas of concern to the Air Force. An annotated bibliography of the literature is presented in a companion report, HumRRO FR-ED(P)-76-36.

Technical monitorship for this effort was provided by Dr. Robert N. Schwartz and Dr. Thomas C. Donohue of the Analysis and Evaluation Group, ACS/Studies and Analysis, Hq., USAF. Their assistance is gratefully acknowledged, as is that of numerous research colleagues in the US and in Europe. In addition, civilian and military flight training and management agencies have provided inputs, and a wide variety of library resources have provided assistance. Particular thanks are due the USAF Air University Library, Maxwell AFB, AL and many of its staff who provided most valuable assistance. Dr. Paul W. Caro, HumRRO, has provided technical input throughout the effort.

This project was performed under AFOSR Contract No. F44620-76-C-0106.

I. BACKGROUND AND PROBLEM

INTRODUCTION

Management of its rated pilot manpower resource is a major concern of the US Air Force (USAF). Not only does the pilot resource represent a sizable fiscal investment in terms of the costs of initial training of pilots to operational proficiency levels and the further training investment required to maintain these skills, the skills represented in the pilot resource must be sufficient to meet current and potential operational requirements. This readiness requirement is the major concern in Air Force manpower management.

A principal focal point in pilot resource management relates to programs to maintain or retrain pilot skills once they have been acquired. In examining questions concerning pilot manpower management policies, the Office of the Assistant Chief of Staff, Studies and Analysis, Hq., USAF, has identified long-term retention of flying skills as an area of prime importance to the formulation of effective pilot resource management policies. Accordingly, it was decided that a starting point for USAF investigation of this subject should be a review of the literature on long-term retention of flying skills, particularly the behavioral science literature. This report presents major points of that literature and relates them to USAF concern with reference to long-term retention of piloting skills. An annotated bibliography resulting from the literature review is presented in a companion report.[1/]

1/ Prophet, W.W. Long-Term Retention of Flying Skills: An Annotated Bibliography. HumRRO FR-ED(P)-76-36, Human Resources Research Organization, Alexandria, VA, October, 1976.

BACKGROUND

The United States Air Force, perhaps to a degree greater than ever before in its history, finds itself faced with an increasingly difficult problem of maintaining combat readiness in a time of mounting concern over resource availability. The scope of possible combat contingencies facing the USAF is increasingly broad, and the equipment to meet those contingencies, while of significantly greater operational capability than that of the past, has become significantly more expensive to procure, operate, and maintain. Obviously, availability of fiscal resources is a matter of major concern to the Department of Defense (DoD), for defense must compete with other national programs for federal funding priority. Similarly, within DoD, USAF requirements must compete with others for available funds.

Important though these fiscal concerns are, in 1973 a new dimension was added that may ultimately be of more concern than the availability of fiscal resources. The reference is to the oil embargo and the availability of fuel resources. This occurrence brought home most forcefully the potentially severe limitations on operations of the military services and, in fact, on the entire U.S. society and economy, that result from our major dependence on oil as the basic fuel, particularly foreign oil. While the embargo and its aftermath have brought staggering increases in the cost of fuel, more important is the fact that for the first time the USAF and the other services are faced with a possibly severe restriction on flying activities that cannot be wholly remedied by more money or more efficient fuel logistics. It is a time for careful examination of resources and their management.

This situation has consequences that affect practically all aspects of DoD programs, but a major area of USAF concern is the cost attendant to its

flying hour program and how to achieve maximum cost effectiveness for that program. The flying hour program, which supports both USAF flight operations and training, represents a major budget item and, thus, is a prime object for management concern and attention, both by DoD and the Congress.

Some idea of the concern over this management problem can be gained from a recent report[1/] by the General Accounting Office (GAO) on the flying hour programs of the military services. This "Report to the Congress" states quite succinctly the costs, the importance, and some of the problems of service flying-hour programs. The following quotes are illustrative:

> "The military services flew about 6.4 million hours in fiscal year 1975 at a cost of about $2.7 billion. A large part of this flying was for transporting personnel and cargo, for surveillance, and for similar operational-type flying. But most of this flying was for training to develop and maintain pilot-flying proficiency as an element of military readiness." (p.1)

> "The military services' flying-hour programs are a multibillion-dollar operation and a key ingredient for maintaining a combat-ready defense posture. The cost of increasing or decreasing flying is fairly easy to measure; the impact on training and readiness is not. Although it is generally recognized that periodic flying enhances training and readiness, it is difficult to establish how much is enough to achieve desired levels of proficiency. Varying types of aircraft and unit missions, the experience and previous training of the pilots and crews, and locations influence the amount of flying and its relationship to training and readiness.
>
> In recent years fuel has become scarce and expensive. Even though the military services have reduced the number of hours flown, costs have increased. The need to maintain defined levels of readiness still remains and therefore, makes it imperative that maximum benefits be obtained from available flying hours. Effective development and management of the flying-hour programs thus becomes critical, if training and readiness objectives are to be met." (p.3)

1/ Comptroller General of the United States. Flying Hour Programs of the Military Services: Opportunities for Improved Management. LCD-75-451, United States General Accounting Office, Washington, DC, June 18, 1976.

As suggested, there are many aspects related to the management of the USAF flying-hour program, but it is those aspects related to training that are of concern here. Training is for the purpose of producing a force with the skills required to carry out USAF combat and non-combat operational requirements. While it is not necessary to review all aspects of USAF flight training in detail here, an overview of such training, as it relates to the current concern with long-term flight skill retention, is appropriate.

USAF TRAINING AND SKILL RETENTION

The process of training a combat-effective USAF pilot is a lengthy one. In order to reach the proficiency levels required for combat operations, the pilot must complete Undergraduate Pilot Training (UPT) and training in an operational aircraft at one of the Combat Crew Training Schools (CCTS). Subsequent to completing CCTS, the normal career pattern for the young USAF pilot would be assignment to a major command operational unit where he engages in regular flying duties as a member of that unit. During this and subsequent such assignments, the pilot increases his proficiency in the basic skill areas covered by UPT and CCTS and acquires additional skills specific to the operational missions of the unit to which he is assigned. Having reached this level, the pilot continues to fly training and operational missions that serve to maintain his skills at the level required for operational readiness.

As long as the Air Force pilot is in a flying assignment, maintaining required skill levels does not seem to be a major problem, though USAF devotes continuing attention to assure this result. However, the USAF pilot does not spend his entire career in flying assignments. A wide variety of other skills is required of USAF officers, both rated and non-rated, for

the USAF to function effectively. Consequently, the USAF career pilot, after his initial or a subsequent cockpit tour,[1/] typically is assigned to one or more of a variety of career-broadening assignments such as staff duty, advanced military education, or possibly advanced civilian education. In such an assignment he becomes part of the "rated supplement," that force of rated pilots in non-flying assignments who are available to fill cockpit positions in the event of national emergency or during subsequent assignments. In order to prevent their piloting skills from deteriorating unduly during such non-flying assignments, most pilots in the rated supplement have been required to engage in proficiency flying (PF) in which they are required to fly some minimum number of hours per calendar period. Such flying is referred to as continuation training. While the amount of proficiency flying required has varied from time to time and service to service, it has generally been in the range of 80-120 hours per year. The exact basis on which these PF requirements were established is not known, but it seems certain that it was not on the basis of research data.

It has generally been held that flying skills must be exercised regularly if they are to remain at the level required by USAF combat readiness requirements. While we are all aware of popularly held positions with reference to the relative permanence over time of certain complex human motor skills in the absence of practice (e.g., bicycle riding, swimming, playing the piano, etc), no one seriously questions the need that pilot skills be in a state of currency if pilot performance is to be safe and effective. In real life, seldom are we required to perform non-flying skills in a situation fraught with the stress, safety, and time-press considerations that characterize aviation. Even the accomplished pianist who might demonstrate convincingly that he can play with perhaps considerable

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[1/] Since 1970, the new pilot is obligated to serve at least five years in a cockpit assignment after completion of UPT.

competence after several years without serious practice, or perhaps with no practice at all, would not likely wish to appear in concert without having undergone a regimen of recent systematic and intensive practice. In considering the skills of the pilot, the USAF must be concerned not only with the stringent requirements attendant to operating the aircraft in a manner that guarantees a high probability of safety for the aircrew, passengers, and others, but, even more important, it must be concerned with guarantees of mission accomplishment. It is in striking the proper balance among mission requirements, training, skill maintenance requirements, and available resources that the crux of the resource management problem lies.

As has been mentioned, the possibility that available resources will not allow continuance of proficiency flying programs for some or all rated supplement pilots has become one whose consequences the Air Force must examine. Even granting that resources might permit some sort of continuation training, the Air Force must examine seriously the benefits and costs of alternative methods of force management under current and future conditions of resource limitation.

SABER WINGS II

The general question of how best to maintain required skill levels, or how to regain them if they are not maintained, is an exceedingly complex one. The problem, when viewed in a systems context, involves national defense policy, world affairs, the inter-relations among combat and logistic systems, military management factors, and a variety of matters far beyond the concern of this paper. However, a fundamental aspect of the problem, one to which this paper is addressed, is that the problem is first and foremost a behavioral one that deals with the acquisition, retention, and reacquisition of flying skills by pilots.

The Office of the Assistant Chief of Staff, Studies and Analysis, Hq., USAF, has undertaken a major study concerned with the general problems of management of pilot manpower resources under the title, SABER WINGS II.[1/] The focus of that study is maintaining required levels of pilot readiness with the least expenditure of training, personnel, and fuel resources. It is recognized that questions relating to retention of flying skills as a function of amount and type of flying activity are significant to the study. As a consequence, the present effort was undertaken to provide behavioral science input to the SABER WINGS II effort.

In seeking to achieve maximum cost benefits in its force management policies, the Air Force must be concerned with a number of questions such as the following:

- What level of proficiency defines the "combat-ready pilot?"
- How does one measure combat readiness of individuals, crews, and units?
- What are the most effective and efficient means of achieving combat-ready proficiency levels?
- How much and what kind of training or exercise is required to maintain combat-ready proficiency levels?
- What happens to proficiency levels, over time, as a function of amount and type of continuation (proficiency) training?
- Are current proficiency flying programs effective?
- Is any proficiency flying required for rated supplement personnel?
- What are the effects of various proficiency flying program alternatives (including no aircraft flying) on pilot motivation, morale, and retention in service?

[1/] This title stems from an earlier USAF study entitled, A Study of Pilot Proficiency Flying (Saber Wings). This earlier effort is discussed elsewhere in this report.

- What is the likelihood that a pilot will become "unviable" if he engages in no proficiency flying during a non-flying assignment?

This last question concerning the "unviable" pilot requires further comment. There is no precise definition for the concept of pilot viability, but generally, as used here, it refers to the potential capability of the pilot to assume or reassume cockpit responsibilities in an effective manner, in timely fashion, and at a (re)training cost that is reasonable. It is sometimes suggested that major commands are reluctant to accept a pilot for a cockpit assignment after a period of non-flying, or that after a certain age the pilot should not receive certain kinds of CCTS training (e.g., fighter) because of higher than normal probability of failure in CCTS, adverse safety factors, or operational ineffectiveness. Others have maintained that continuity of exposure to the rigors of flight is necessary if motivation to fly is to be maintained or if the pilot is to maintain his ability to perform effectively under stress. As can be surmised, pilot viability is a function of many factors -- age, motivation, career and family interests, flight experience, and the like. While all such factors are of potential interest to SABER WINGS II, the present report generally seeks to examine only long-term skill retention, and factors closely related thereto, as they pertain to the concept of pilot viability.

The question addressed here deals with what happens to pilot flying skills over extended periods of non-flying. If they deteriorate in a fashion that precludes their cost-effective reinstatement for all or some pilots (e.g., certain age or experience groups), then the concept of the unviable pilot becomes of concern in the management of the rated force. The possibility of identifying such unviable pilots would be of interest and would be a behavioral question. Remedial measures (e.g., use of simulators,

targeted proficiency flying, "peaking" of pilot skills prior to a non-flying episode to minimize skill decay, etc.) designed to maximize pilot viability would be of interest. Thus, there are a number of areas of behavioral concern relevant to pilot viability that require information on factors related to long-term flying skill retention and skill reacquisition. It was with this general orientation that the review of the literature reported here was undertaken.

The next section of this report deals with the methodology and procedures employed in this review. Subsequent sections present comments on the literature reviewed and relate the literature to Air Force problems being addressed in the SABER WINGS II effort. Finally, certain conclusions and recommendations for Air Force consideration are presented.

II. STUDY OBJECTIVE AND METHOD

OBJECTIVE

This effort was undertaken in support of the SABER WINGS II study with the general objective of reviewing the behavioral science literature on long-term retention of flying skills and deriving implications for future USAF policies relating to management of the rated force. In addition, information was desired concerning ongoing research activities relevant to long-term flight skill retention. Consequently, the effort reported here was broken into three principal activities: (1) survey and review of literature sources; (2) survey of activities and experience of selected research and operational agencies; and (3) survey of selected knowledgeable research personnel.

METHOD

The methods used in carrying out the three main thrusts of the activity are described below. Since this is basically a literature survey and the methods used were conventional, discussions of the methods will be kept relatively brief.

Literature Survey

The general methodology of the literature survey is described in the annotated bibliography[1/] which is a companion to the present report. It involved search of various HumRRO libraries, principally that of the HumRRO Pensacola Office, and search of Defense Documentation Center (DDC) and National Technical Information Service (NTIS) sources. Libraries consulted are listed in the Appendix. In addition, some documents were contributed by various professional colleagues. The general behavioral science literature

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1/ Prophet, W.W. Long-Term Retention of Flying Skills: An Annotated Bibliography. HumRRO FR-ED(P)-76-36, Human Resources Research Organization, Alexandria, VA, October 1976.

was accessed through Psychological Abstracts and Dissertation Abstracts. Many titles were secured from previous research studies and, in particular, the earlier literature reviews of Smode, Hall, and Meyer (1966), Wright (1969), Gardlin and Sitterley (1972), and Smith and Matheny (1976).[1/]

In all, approximately 2,000 references were "reviewed" at the level of reading an abstract or reference to the item in another source. Of course, only a minority of these items were really pertinent. The annotated bibliography lists some 120 citations for which abstracts or annotations are presented. However, even a minority of these are of central concern, so many of the annotations are quite brief. Also, there are some instances in which a single research effort may be reported in several different citations, e.g., as a technical report and as an article in a professional journal. In addition, the annotated bibliography lists some 80 other references, not annotated, which were reviewed, but were evaluated as "not pertinent." These latter are listed for reader information only, in view of the fact that many have titles or abstracts that sounded pertinent but, in fact, were not.

Agency Survey

In addition to libraries and various other documentary sources, a survey was conducted of selected research laboratories, university or college agencies, airlines, and federal and other agencies concerning their activities, experiences, or programs that might deal with long-term flight skill retention. These various agencies are listed in the Appendix.

[1/] Reference to documents covered in the basic bibliographic listing of the annotated bibliography companion report (HumRRO FR-ED(P)-76-36) will be made in the above fashion in the present report. Such items discussed in the present report are listed in the bibliography at the end of this report. This listing is less extensive than that of the annotated bibliography since not all items covered in the annotated bibliography are discussed here. Reference in the present report to items not listed in the annotated bibliography report will be through the use of footnote citations as were used in Chapter I.

Contact with these agencies was by mail or telephone primarily, but in some cases visits were made by the author or an associate. Information sought was of several types:

(1) Specific programs or research concerned with long-term flight skill retention. For example, were any of the service laboratories engaged in research on the subject, have the airlines analyzed data dealing with retraining of pilots after extended non-flying periods, etc.

(2) Knowledge of programs or research by other agencies.

(3) Suggestions as to persons to contact.

(4) General comments on long-term flight skill retention.

Survey of Individuals

Certain individuals likely to be knowledgeable concerning long-term retention of flight skills were contacted face-to-face, by mail, or by telephone. In some cases, these individuals were affiliated with one of the agencies contacted, but in other instances they were contacted because of their general expertise, rather than agency affiliation. These persons were colleagues known to the author or suggested by others as likely sources of informed input. The individuals are listed in the Appendix.

By fortunate temporal coincidence, one of the research staff on this project was presenting a paper[1/] in England and consulting with the Royal Swedish Air Force during the conduct of the present survey activities. This allowed contact to be made with personnel from European agencies, and at the RAF Institute of Aviation Medicine, concerning research activities in Europe related to long-term flight skill retention. While there was considerable interest in the problem area and anecdotal information was offered,

1/ Caro, P.W. Some Factors Influencing Transfer of Simulator Training. Paper for Third Flight Simulation Symposium of the Royal Aeronautical Society, London, England, April 1976. Published as HumRRO Professional Paper 1-76, Human Resources Research Organization, Alexandria, VA, August 1976.

unfortunately no documentation or reports of research or other efforts of significance in the present context were found.

GENERAL SCOPE OF SURVEY

While further search would undoubtedly turn up additional items of interest, it is felt that most of the major extant items on the subject were located and are represented in the two reports that resulted. The topic of long-term flight skill retention is not a new one, obviously, and its importance has been recognized for many years, as evidenced by the fact that research on the subject has been conducted. However, the amount of research and data revealed in the present examination seems meager when compared with the potential importance of the topic.

It should be noted here that the focus of the present review was kept somewhat narrow in the sense that emphasis was on direct studies of flight skills or of skills that could be easily related to the flight situation. No attempt was made to cover in depth the academic and research literature dealing with the general subjects of learning and retention. The bulk of this literature deals with verbal learning, as opposed to skills learning, and is voluminous far beyond the capability of the present study's resources to cover. More important, it is of marginal interest in the present context of providing input for USAF policies on flying programs and force management. However, that literature is adequately represented here in the competent work of Adams (1967), Naylor and Briggs (1961), and others. The focusing of the present search on motor skills retention, particularly flight related skills, in no way is intended to denigrate the quality or importance of the more general body of literature.

III. RESULTS

THE NATURE OF FLYING SKILLS

Before discussing the literature on long-term retention of flying skills, it may be advantageous to discuss the nature of the USAF pilot's task and the flying skills of concern here. It is clear that the tasks the pilot of a modern military aircraft must perform are many and complex. There are few task situations that demand as much of the performer in terms of physical strength and endurance, fine perceptual and motor discriminations, cognitive functioning, verbal communication skills, decision making, and the like, as does that of flying an aircraft. Also, there are few performance environments or situations that produce the task-time press, the general physiological and psychological stress, and bodily-harm threat as does the flight situation, particularly in the combat setting.

Prior Research

If one sought to deduce the nature of the pilot's task from the content of the research literature, he might conclude that it is fairly simple, consisting mainly of requirements to track erratically moving spots of light on the face of CRTs through manipulation of a joy-stick control, or he might conclude that it consisted of rapidly manipulating toggle switches or pushing buttons in response to multi-colored and multi-patterned displays of flashing lights. In fact, a substantial number of studies in the aviation psychology literature have involved variants of one or the other of these types of tasks because there has been a great emphasis on the study of tracking and procedural task skills. These two dimensions are undoubtedly critical components of pilot skills, but there are others that have received considerably less research attention.

One reason for the emphasis described above, of course, is that of

amenability to experimental control and the production of reliable data. Another and more important factor, however, is that most researchers concerned with aviation skills have been primarily interested, in one way or another, in the initial acquisition of pilot skills and in factors that facilitate or inhibit such acquisition. Consequently, there has been much more research attention devoted to skill acquisition at the UPT skill level than at advanced skill levels. Since much of the learning activity involved at the UPT skill level is related to the perceptual-motor skills required to control the aircraft in space with some degree of precision and reliability (tracking), and in learning the complex spatial-temporal relationships that relate to execution of tasks in the cockpit environment (procedures), the research emphasis is not surprising. Neither is it surprising that this conception of the pilot's task is also reflected in much of the retention research examined here.

Phases of Skill Acquisition

As a framework for examining research on pilot skill acquisition, the discussion of phases in the acquisition of complex perceptual-motor skills by Smode, Hall, and Meyer (1966) is of some interest. Their account, which leans heavily on ideas advanced by Fitts,[1/] describes three phases in skill acquisition: (1) the Early (Cognitive) Phase; (2) the Intermediate (Fixation) Phase; and (3) the Late (Autonomous) Phase. In the early phase the student seeks to develop a cognitive structure of the task that will allow him to practice it, while in the second, or fixation, phase the perceptual and response patterns are fixed through practice so that there is less and less reliance on verbal mediation of response integration. UPT training,

1/ Fitts, P.M. "Factors in Complex Skill Training." In R. Glaser (Ed.) Training Research and Education. Pittsburgh: University of Pittsburgh Press, 1962, 177-197.

and probably at least the initial CCTS training course, can be classified as spanning these first two phases.

It is performance during the third phase of skill development that is of most interest to the USAF with reference to the long-term retention area. As noted earlier, Air Force concern in this area is related to management of personnel at very high skill levels, personnel who have undergone one or more operational tours before being faced with a non-flying assignment. The comments of Smode, Hall and Meyer (1966) concerning this third phase are worthy of quoting:

> "This phase, for which little experimental data are available, represents a very gradual, but continuing, improvement in proficiency. In addition, performance becomes more resistant to stress and to interference from other activities that may be performed concurrently. Fitts refers to neurological evidence indicating less and less involvement of cortical associative areas as learning continues in the case of simple conditioned-response learning, thus supporting the idea that this stage of autonomous behavior is based on a shift from reliance on visual to reliance on proprioceptive feedback, a shift of control to lower brain centers, and similar changes." (p. 26)

This third phase is seen as spanning some years as the pilot or performer approaches the performance peak that is characteristic of the true professional pilot. In fact, it is suggested that this slow increase in competence might continue indefinitely with regular, intensive practice, were it not for the effects of physiological aging and/or loss of motivation. The point to be noted here is that this is the phase of the acquisition process, or really, the phase of the pilot's career, of most interest to the Air Force with reference to skill maintenance/retention/relearning questions; but, it is the one to which the least research attention has been devoted.

Research on Abilities and Skills

While it does not follow that the data on retention or acquisition that have been developed on early and intermediate phase skill levels are

not applicable to the late phase level, there is research that raises some question in this regard. There has been considerable research on the fundamental nature of skills, the development of task or behavioral taxonomies, and related matters. One important line of such research is that of Fleishman and his associates concerned with the factorial structure of motor skills. While systematic review of this area of psychological research is beyond the scope of this paper, several studies are relevant. In one, Fleishman and Ornstein (1960) investigated the underlying ability structure of flying performance at various levels of training, while in another series of investigations (Parker and Fleishman (1959), Parker and Fleishman (1960), Fleishman and Parker (1962)), the relationship of ability factors to skill retention was investigated. The aspect of these investigations of interest to the present discussion is Fleishman's contention that the structure of the task, in terms of human ability factors[1/] required for its performance, changes with level of skill or amount of practice. Thus, according to this line of reasoning, the set of ability factors required for success in early UPT training is different from that required at a mid-point, and both sets might differ from the set of abilities required later in training. If this be the case, it is reasonable to assume that there is further change as the experienced pilot moves into and through the third phase of skill acquisition described by Smode, Hall, and Meyer (1966). It is also possible that retention research based on ability structures characteristic of earlier stages of skill development might produce

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1/ A distinction is made here between "ability" and "skill." An ability is conceived as a fundamental, stable aspect of the individual such as verbal reasoning ability, while skills are acquired or learned ways of using abilities. Thus, according to this conception, one may acquire varying levels of skill in a verbal reasoning task, depending on practice and the amount of underlying ability, but the ability does not change.

results and conclusions different from those that would be found at the more advanced stage, a stage for which, unfortunately, all too little research has been done.

The matter is further complicated by the line of research that suggests that, rather than the character of the task changing with practice while the underlying abilities of the individual remain constant, it is the basic ability structure of the individual that changes while the task structure remains constant. In a series of papers by Hulin and Alvares (1971, a,b,c) they conclude that the data support a third, or combination, model and that both types of changes occur in the acquisition of flying skill. The importance of such research to the present context lies in the possibility that not only are we faced with the change in skill level over time during non-flying or reduced flying periods (the retention/decrement function), but that there may be changes in both the task structure and the individual's underlying abilities. As stated, there is too little research dealing with advanced skill levels to provide a sound basis for conclusions on questions of this sort.

The Pilot as Information Processor

However, the subject of the nature of the flying skills of the operational USAF pilot can be viewed in less esoteric terms. It can be maintained on a basis of rational analysis of the tasks involved that the more critical aspects of advanced flying skill levels are those dealing with identification and acquisition of relevant information (in terms of both tactical and aircraft situations), the processing of such information, decision making, system management (including tactical, aircraft, and human systems), and similar "higher level" functions. Another critical aspect of advanced flying skills often cited is the ability to perform reliably functions such as the preceding (as well as those old favorites, tracking

and procedures) while under conditions of great psychological and physiological stress.

In line with the concept of the skilled pilot as an information processor and executive agent is the work of researchers who have been concerned with the pilot's ability to function in a dual- or multi-task situation. It is assumed that the individual is limited in both information channel and processing ability and, thus, in any given task load situation has only a limited amount of "spare" capacity or attention that can be devoted to other tasks. As pilot skill increases, this residual or spare capacity increases as perceptual discriminations and responses are fixated or become autonomous. Hence, the mark of the highly skilled pilot may be that he can take care of the routine aircraft "housekeeping" tasks and have more attention available to devote to tactical management and decision making requirements. A number of researchers have pursued this line of research, as, for example, Gopher and North (1974), who describe a means of measuring operator capacity. But, no studies of flight skills retention based on this conception were found.

As can be deduced from the preceding discussion, the nature of flight skills can be viewed as a fairly simple composite of stimulus-response habit patterns concerned largely with tracking and procedural tasks, or as a much more complex composite of those skills (operating in autonomous or near-autonomous fashion) plus a variety of higher level processes devoted much more to management of the aircraft, weapons, and other personnel as an integrated system in the accomplishment of goal-oriented, mission behavior. The question of long-term retention of flying skills for pilots at the higher, professional skill levels of the USAF pilot population for whom non-flying assignments are a matter of management concern should probably be cast in the more complex view of pilot skills described.

Combat Readiness

Another aspect of the nature of flying skills with which USAF force management is concerned is the definition and measurement of combat readiness. What are the characteristics of the combat-ready pilot, for it is the retention/maintenance/retraining of this level of proficiency with which force management must be concerned. Obviously, pilot skills must be maintained at a level that assures that the USAF can meet its various combat contingency requirements. This carries connotations of level of performance, reliability of performance, numbers of personnel, and time to train, retrain, or reassign personnel to meet surge, drawdown, and rotation requirements. There are a number of alternative force management models that might accomplish these ends at varying costs or with varying trade-off advantages and disadvantages.

As might be deduced from the preceding observations concerning the dearth of research on higher pilot skill levels, the areas of definition and measurement of combat readiness have also been neglected. There are many penetrating analyses of a non-research nature that have been made of these areas -- analyses that may be quite valid -- but relatively little has been accomplished at this level of skill by the behavioral researchers. Some observers have developed positions concerning combat readiness that may be based, at least in part, on behavioral research. For example, Stewart (1971) states (p. 13-14), "To be combat-effective, that is to be capable of performing reliably and accurately under the stress of combat, the pilot must have attained a level of experience (flying hours), judging from the limited evidence available, such as to require about four years of flying after graduation from UPT." Thus, Stewart equates combat readiness with the accumulation of about 1,200 hours of total flight experience. The

difficulty of this approach to defining combat readiness is that it does not say what the skills are, or what levels of proficiency are involved, in a manner that allows objective measurement or consideration of alternative means for achievement. This is not to suggest at all that the development of combat readiness is purely a random, trial-and-error process that occurs in operational units with no management or control. Rather, it is to say that the nature of these skills has not been well articulated, and very little research data on them exist that can be used in force manpower management models. Use of relatively simple indices such as total flying hours, age, rank, etc., in management models is understandable because of their simplicity and availability, and because of lack of more precise behavioral data to use as inputs.

ORGANIZATION OF THE LITERATURE REVIEW

In presenting the results of a survey of literature and information in a topical area, there are numerous alternative ways that one might organize the review. In the present case, the following organization outline will be followed:

1. General comments on the recent literature.
2. Discussion of other general reviews of the literature.
3. Discussion of specific aviation-related studies of skill retention.

No attempt will be made to treat each of the 120 items covered in the companion annotated bibliography,[1/] since many of those items are of minor significance. Rather, the aim will be to treat those items of principal concern to the USAF with reference to long-term retention of flying skills. In the subsequent chapters of this report the literature and other information will be discussed and major conclusions formulated.

1/ Prophet, W.W. Long-Term Retention of Flying Skills: An Annotated Bibliography. HumRRO FR-ED(P)-76-36, Human Resources Research Organization, Alexandria, VA, October 1976.

GENERAL COMMENTS ON THE LITERATURE

Human memory was the first area of psychological content to receive systematic scientific attention. The beginning of scientific study of the area is usually dated from 1885, the year Hermann Ebbinghaus published his classic report of his studies of memory.[1/] Since that time, thousands of papers on memory and retention have been published, dealing primarily with the subject of verbal learning and memory. As has been noted, considerably less attention has been devoted to the retention of perceptual-motor skills than of verbal skills. While the verbal learning literature is of potential significance to USAF concern with flying skill retention, that potential was felt to be so slight that it did not warrant committment to the verbal skills area of a significant portion of the limited resources available for the present review. Fortunately, much of that literature pertinent to long-term retention was reviewed at length by Naylor and Briggs (1961) in their comprehensive paper, so the present review does not cover that ground again.

In examining the literature relevant to flight skills retention, it is obvious that direct concern with this area by the military services is a fairly recent development, essentially dating back only to the late 1950s when the USAF began to consider extended space-flight missions and the demands such missions might make on skill retention. There was some flurry of concern with the topic in the early 1950s when a number of World War II pilots were called back into service during the Korean conflict, but this concern did not result in substantial research programs.

As a result of the emergence of manned spaceflight in the late 1950s

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1/ Ebbinghaus, H. Über das Gedachtnis: Untersuchungen zur experimentellen Psychologie. Duncker and Humbolt, Leipzig, Germany, 1885.

and 1960s, the USAF and NASA embarked on a number of studies of skills retention during the 1960s and 1970s. Concurrent with this development was the appearance in the 1960s of concern by the services with their various programs of proficiency flying (PF) or combat readiness training (CRT). This concern, which was prompted by congressional and budgetary pressures, led to several studies of proficiency flying programs such as that of Caines and Danoff (1967), in which both USAF and USN programs were examined, Kusewitt's (1968) study of Navy CRT programs, the USAF Saber Wings study (1969), the Wright (1969, 1973) and HumRRO (1974) studies of U.S. Army CRT/PF programs. Of these proficiency flying studies, only those of the Army were specifically concerned with flight skill retention after periods of no-flying. The only study of flight skills retention by USAF of recent times was the examination of the retraining records of Vietnam POW returnees, as reported in Armstrong, Bleymaier, Hinkel, Levins, and Sheppard (1975) and in Smith and Matheny (1976). This was a post hoc examination of data of opportunity, rather than a planned investigation.

During the past decade, some investigations of skill retention have also been carried out by the FAA and the airline industry. These studies were not particularly concerned with retention after periods of non-flying, except by chance, since their purposes were more related to decay of aspects of skill among persons still flying or to the training of certain groups as in the upgrading of airline second officers.

One might conclude that with the military services, FAA, NASA, and the airline industry all having some degree of interest in the topic, there would be a good deal of research activity on the subject of long-term retention

of flying skills. Such, unfortunately, is not the case. The USAF-NASA combination has produced some significant research in the spaceflight context, but the USAF has devoted little recent experimental research attention to the subject in the aircraft context. The Navy has given the subject no official attention, other than the Kusewitt (1968) study, which was really aimed at defining the recommended nature of CRT programs, not the studying of retention. Only the Army among the military services has mounted deliberate, experimentally oriented studies of retention during recent times. No current research on the subject by either US or foreign agencies was found to be in progress, so it is not a highly active area.

One way to assess the research activity on long-term flight skills retention is to compare sources covered in the present survey with those of its two major predecessors, Naylor and Briggs (1961), and Gardlin and Sitterley (1972). Naylor and Briggs covered 123 references, while Gardlin and Sitterley had 116. The annotated bibliography [1/] of the present effort contains 120 references. Table 1 shows the publication year of the references covered in these three reviews. While some pre-World War II references are contained in the Naylor and Briggs review, it is apparent that the greatest concentration of research activity has been from 1960 on.

In examining Table 1, it should be kept in mind that there is some overlap among the three reviews, most notably between that of the present author and that of Gardlin and Sitterley (1972). Table 2 depicts the degree of overlap. As can be seen, 36 items are common to the current review and that of Gardlin and Sitterley, while the present review contains 79 items

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[1/] Prophet, W.W. Op. cit.

TABLE 1

PUBLICATIONS REVIEWED - BY YEAR OF PUBLICATION

Year of Publication	Literature Review[1/] Naylor & Briggs	Gardlin & Sitterley	Prophet
1975 -	0	0	6
1970-1974	0	4	40
1965-1969	0	62	40
1960-1964	1	37	25
1955-1959	25	8	6
1950-1954	28	5	1
1945-1949	5	0	1
1940-1944	11	0	1
1935-1939	14	0	0
1930-1934	19	0	0
1925-1929	6	0	0
1920-1924	6	0	0
1915-1919	3	0	0
1910-1914	2	0	0
1905-1909	2	0	0
1900-1904	0	0	0
1895-1899	0	0	0
1890-1894	0	0	0
1885-1889	1	0	0
Total	123	116	120

[1/] Reference is to reviews by Naylor and Briggs (1961), Gardlin and Sitterley (1972), and Prophet (1976) Op. cit.

not in the other two. Only three items are found in all three of the reviews.

TABLE 2

COMMONALITY OF THREE LITERATURE REVIEWS

Author(s)[1/]	Number of Items Reviewed
Naylor only	113
Gardlin only	72
Prophet only	79
Naylor-Gardlin	5
Naylor-Prophet	2
Gardlin-Prophet	36
Naylor-Gardlin-Prophet	3
Total	310

[1/] See footnote, Table 1.

More important, however, is the content of these various studies. Naylor and Briggs (1961) state that most of the literature they cover is concerned with verbal, rather than motor, behavior. They note that published studies of skills retention had appeared at the rate of only about two per year from 1900 to 1960, but that many of those were only tangentially relevant to USAF concern. Gardlin and Sitterley (1972) describe skill retention studies as involving three types of tasks, generally: (1) simulation tasks; (2) tasks involving essential elements; and (3) abstract tasks of only peripheral relevance. The latter category, they state, is descriptive of the majority of studies in the Naylor and Briggs review. In the more recent literature, the second, or essential elements, type of task accounts for most of the research, while the use of simulation is receiving increasing attention in skill retention studies. As might be deduced from these comments, direct studies of flight skills retention in the actual flight setting are few in number.

In terms of research content of the more recent studies, length of retention interval, level of pre-retention interval proficiency, effects of rehearsal, use of simulation in retraining, and transfer task fidelity are some of the major variables studied. Others include task type (e.g., tracking vs. procedure), age, and task organization. However, most of these variables have not been attended to as part of an integrated research effort concerned with pilot skills retention. It is unfortunate that the suggestions for development of an integrated research approach on long-term flight skills retention, such as advanced by Naylor and Briggs (1961) and Smode, Hall, and Meyer (1966), have not been pursued by the USAF and others to develop the data base and conceptual understanding needed for current and future force management policy determinations.

PREVIOUS LITERATURE REVIEWS

As has been noted, the Naylor and Briggs (1961) review is generally acknowledged as the first major review of long-term skills retention relevant to current USAF concerns. Subsequent reviews (e.g., Smode, Hall, and Meyer (1966), Wright (1969), and Gardlin and Sitterley (1972)) have relied on Naylor and Briggs as an adequate summary of the literature for the first 60 years of this century. The present effort affirms that view of Naylor and Briggs as an excellent summary. While we do not intend here to examine the Naylor and Briggs review in detail, its major conclusions will be discussed as they relate to our topic of concern. For more extensive treatment of their reivew, the reader is referred to the original document (Naylor and Briggs (1961)), to the Gardlin and Sitterley (1972) review, or to the annotated bibliography[1/] companion to this report.

[1/] Prophet, W.W. Op. cit.

The other major review of interest is that of Gardlin and Sitterley (1972). Their review was motivated by an interest quite similar to the present one, i.e., NASA's interest in long-term retention of piloting skills, except for spacecraft rather than aircraft. They review some 116 items, of which 99 are dated in the 1960s. Thus, their review can be characterized as covering the decade of the 1960s. It also contains more studies of direct pertinence to our present context than did the Naylor and Briggs (1961) review.

The present review, as reflected in the companion report,[1/] cannot really be characterized as covering the decade of the 1970s because of its date, but 46 (38%) of the 120 items reviewed were published 1970 or later. Some 50% of the items carry 1960s publication dates, while the 1950s and 1940s account for only 6% and 2%, respectively.

While there is some overlap in coverage, as noted, among the three reviews, it can be seen that there has been an increasing flow of research dealing with the subject of long-term skills retention. It would be a mistake to assume, however, that the problem is receiving adequate research attention, for of the several hundred studies included in this review, only a relative handful deal with skills of the magnitude of complexity of aircraft piloting, and very few deal with retention time intervals similar to those of concern to the USAF (1-3 years).

[1/] Prophet, W.W. Op. cit.

Naylor and Briggs Review

It is of interest to note that in their literature review, conducted for the Air Force in anticipation of extended spaceflight missions for USAF personnel, Naylor and Briggs (1961) stated that the state of information was not only deplorable academically, but ". . . it is rapidly becoming intolerable from a practical point of view." In spite of the deficiencies of the literature, Naylor and Briggs were able to provide a milestone summary that is still useful. Because of the diversity of the more general literature covered in their review and its general lack of pertinence to flight tasks, it was necessary that they develop a schema that would allow relating the literature to flying. To this end, they classified the literature on the basis of four types of variables: (1) task variables; (2) learning variables; (3) retention interval variables; and (4) recall variables. Brief discussions of their major conclusions in each of these areas follow.

Task Variables. Naylor and Briggs conclude that the literature does not support the contention that motor tasks are better retained than verbal tasks, though they do note that continuous control tasks show superior retention to discrete procedural tasks. This finding, they feel, is more a reflection of the greater retentivity of tasks that have a higher internal logical structure (task integration).

Learning Variables. Their principal conclusion of interest here is that the higher the level of original learning, the higher is the amount retained. Also of interest is their observation that, while distributed practice during original learning may result in faster skill acquisition, it does not seem to affect retention.

Retention Interval Variables. Naylor and Briggs cite length of the retention interval (i.e., the no-practice period) as a powerful factor in

retention, albeit one that may act through operant mechanisms other than time per se, for example, habit interference. They do not feel that there is a single decrement function curve, but rather that decrement is specific to the task and situation. The beneficial effects of rehearsal during the retention interval are noted, with the effect increasing as the similarity of the rehearsal task to the recall or criterion task increases.

Recall Variables. The major conclusions in this area of current concern relate to the positive influence of increasing similarity between recall task and original task, and the beneficial effects of warm-up activity. A conclusion of considerable methodological import is their observation that amount of retention, as measured experimentally, is a function of the type of recall measure used. This point has practical, or applied, import as well as theoretical, since the individual attempting to use research data in real-world situations must be aware of measurement influences.

Naylor and Briggs recognized clearly the inadequate state of information and the need for programmatic research on long-term retention of skills. They called for new research on two points in particular, task organization and measurement methodology.

Gardlin and Sitterley Review

The other major review of interest here is that of Gardlin and Sitterley (1972). In reviewing the literature of the 1960s, they note that popular areas of investigation included type and amount of training, task organization, equipment parameters, rehearsal, and secondary task interference. The authors organize the results of their literature review under four headings: (1) amount of training; (2) duration of retention interval; (3) task organization; and (4) task environment.

Amount of Training. Gardlin and Sitterley conclude from their review that amount of training is positively and influentially related to amount retained. However, they note that absolute loss in performance for any given task-retention interval combination is not differentially affected by amount of training. They state that ". . . it may be concluded that the type of training which produces the highest level of performance will also produce the best retention test performance."

Duration of Retention Interval. In reviewing this area, they note that, "unsurprisingly," longer retention intervals produce greater skill loss and lower initial retention test performance. They highlight a point of considerable concern to those attempting to apply research data on retention, i.e., that retention data are highly specific to the task and situation studied. They note, for example, that results using a two-year retention interval have varied from the "no noticeable decrement" of Fleishman and Parker (1962) to the significant decrements observed by Ammons et al (1958). Of interest, too, is Gardlin and Sitterley's observation that while both tracking and procedural skills show increasing decrements as retention interval increases, and while both types of skills can be restored (retrained) to original levels in considerably less time than required for original learning, the time required to retrain procedural skills is relatively much greater than that for tracking skills. With reference to procedural tasks, they note that commissive errors are most affected by time interval. They also note that practice and warm-up are beneficial to performance regardless of time interval.

Task Organization. Effects of task organization were noted to be contingent on degree of original training with retention of lesser trained

subjects being higher for tasks with high organization. Thus, the authors state, ". . . the key factor in predicting skill retention for a given no-practice interval appears to be the final level of skill acquisition. Other variables were seen only to modify this level."

Task Environment. Factors studied in this area of their review included display-control relationships, degree of fidelity in training devices, display specificity, augmented feedback, and visual noise. Gardlin and Sitterley indicate that equipment factors are important to retention, principally, as they affect the level of skill achieved in original learning, and in similarity of retention task environment to original task environment.

In discussing the results of their review, Gardlin and Sitterley conclude that level of performance prior to the retention interval is the primary predictor of retention for any retention interval. They note that there has been little attention devoted to the characteristics of those individuals who achieve high levels of performance. Research in this area would be desirable, they state, as would research related to temporal skills and to performance measurement. Additional research needs cited include the effects of environmental and psychological stress on retention and establishment of relationships between the simplified laboratory tasks used in most retention studies and the real-world tasks in which the applied researcher is interested. It is lack of relationship data, they point out, that makes it difficult to use the research data to predict retention in specific situations.

Other Literature Reviews

Other researchers have conducted reviews of the skills retention literature, but generally of a more restricted scope than those discussed.

Wright (1969) reviewed the behavioral science literature (76 references) as it pertained to Army proficiency flying programs. His review has not been widely available to the research audience, but it served as background to his subsequent study (Wright (1973)) of retention of flying skills and retraining requirements among Army aviators. His conclusions in his review (1969) concerning retention included the following: (1) flight skills are retained well for periods up to two years, and retraining is rapid; (2) procedural skills lacking internal organization are rapidly forgotten; (3) the greater the amount of original learning, the greater the retention; (4) forgetting curves for flight skills show negative acceleration; (5) retention is a function of task organization; (6) mental rehearsal facilitates performance; (7) degree of activity in rehearsal is positively related to degree of recall; and (8) initial retention performance is affected by the similarity of both the original learning task and interpolated tasks to the retention task. Wright draws the general implication that the least-cost option for the Army would be complete cessation of proficiency flying during non-flying assignments followed by retraining specific to the next assignment. He pushes for use of training devices in the maintenance and retraining of flight skills.

Smith and Matheny (1976) recently examined the question of continuation versus recurrent pilot training as a means of maintaining required force readiness among USAF rated supplement pilots. They review briefly 15 references pertaining to proficiency flying and related matters, and they present data on USAF pilot POW-returnee retraining.[1/] Their general conclusions from their review are similar to those of Wright (1969). In addition, they

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[1/] The POW data are discussed in the next section of this report dealing with aviation-related retention studies.

conclude that USAF pilots can be retrained in contact and instrument flight skills in 50 hours or less after extended periods of non-flying. They recommend that existing continuation training for USAF rated supplement pilots be reexamined to determine if recurrent training might be feasible and more cost effective than continuation training and to determine the most effective use of ground training devices in maintaining/regaining pilot proficiency.

The only other major literature review of direct concern to the present study is the exhaustive review of Smode, Hall, and Meyer (1966). While their scope was far wider than long-term retention of flying skills -- their concern was research relevant to pilot training -- they devote one section of their review (pp. 168-176) to the subject, "Retention of Flying Skills." Only 16 references are cited in that section, but their observations on the research issued concerning retention are of interest. They note the need for new approaches, stating (p. 175): "Research on retention, as presently conceived, has reached an impasse. The same conclusions continue to be generated with very little additional substance added." They call for programmatic research on forgetting in terms of the characteristics of complex tasks and over longer periods of time, and they also note the need for a better understanding of and means for measuring levels of learning in flight tasks. Unfortunately, their advice has not been well taken.

FLIGHT SKILL RETENTION STUDIES

Air University and Naval Postgraduate School Studies

As has been noted, the number of direct studies of flight skills retention, particularly for relatively long time periods, has been fairly small. The general subject, particularly as it relates to proficiency flying, has received a good deal of attention in a variety of analytical studies by USAF and USN students at the Air University and the Naval Postgraduate School, respectively (e.g., see Armstrong, Bleymaier, Hinkel, Levins, and Sheppard (1975), Becker (1965), Hanley (1971), and Wellington (1972)). And, in fact, while the majority of such efforts have been in the nature of reviews of other sources, some of these student efforts have developed original data of some interest. For example, Schrady and Hanley (1971) gathered actual inflight proficiency data in making comparisons of the effects of 4-hour and 8-hour per month CRT programs. Their use of a semi-objective checklist for measuring flight performance is notable. While they found differences in flight performance favoring the 8-hour per month group, the differences were not statistically significant. However, their data tell us little about retention after non-flying periods. In contrast, Smittle (1975) investigated reaction time to a simulated flight stimulus for Naval aviators who were current and those who had not flown for 60 days or more. No significant difference was found. In another student effort, Wilson (1973) made comparisons of aviator performance of a simulated carrier landing task among three groups; (a) those who were current; (b) a group who had not flown for about one year; and (c) a group who had not flown for about two years. No significant differences were found among those groups, but when the Ss were classified on flight experience, those with less than 500 hours performed less well ($p<.10$) than those at higher experience levels.

In another student study, Shaver (1971) presents data on Navy and Marine training accidents during the first and second 3-month period of Combat Replacement Air Wing (CRAW)[1/] training for aviators who had been in CRT status and those in non-CRT status during immediately prior non-flying assignments. Accident rates per 10,000 hours were 0.833 and 1.269 for the CRT and non-CRT jet pilot groups, respectively, during the first 3-month period. During the second 3-month period the rates were 0.620 and 0.637. While these data suggest that there may be an increase in accidents during retraining subsequent to a non-flying period, they also show that the difference disappears rapidly. Also, the author notes that the accident experience of the CRT group during the period in which they were engaged in CRT flying should be added to their CRAW experience for a sounder comparison.

Data of some direct interest in the present context are contained in another student study, Tice's (1973) Air University examination of navigator proficiency flying requirements. He cites data based on training performance at KC-135 navigator CCTS for 31 B-58 Defensive Systems Operators (DSO) who were being retrained as navigators after several years as DSOs. While these personnel were originally trained as navigators, only one had ever flown operationally as a navigator. Failure rate for the DSO group in the KC-135 navigator program was 6.7% versus 15% for regular students. The author concludes that navigator skills are retained quite well over extended periods of no practice. The commonality of skills required in pilot and navigator jobs would suggest likely high retention of navigation skills among pilot populations. However, these conclusions must be tempered by the fact that the DSOs were regularly engaged in flying missions, even though in a non-navigator role.

[1/] CRAW training is analogous to USAF CCTS training.

One other student study, that of Armstrong et al (1975) dealing with the retraining of POWs, will be discussed in the next section in conjunction with the Smith and Matheny (1976) treatment of the same subject. While these efforts by USAF and USN students were necessarily limited in their data generating capabilities, it can be argued that they represent the only quasi-experimental approaches to the long-term retention problem on the part of the Air Force and the Navy for more than a decade. The only published, officially sanctioned and supported efforts by USAF and USN since the early 1960s uncovered in this review are the Smith and Matheny (1976) review, the Saber Wings study (United States Air Force (1969), the Kusewitt (1968) examination of Navy CRT programs, and the Caines and Danoff (1967) examination of CRT programs performed for DoD. Even adding the study of spaceflight crew retention of Cotterman and Wood (1967), conducted by the USAF Aerospace Medical Research Laboratories jointly with NASA, it is apparent that the Air Force and Navy have not been highly active in the area of direct studies of flight skill retention.

Military/NASA Retention Studies

The study of Mengelkoch, Adams, and Gainer (1960) is [illegible]nitor of direct studies of retention of complex flying skills. U[illegible] simulator for the SNJ aircraft, they examined retention of complex inst[illegible]nt flying skills over a 4-month interval. Their results indicated that, whereas substantial and important decrement occurred in procedural skills, the loss of aircraft control skills was negligible over the time period. They concluded that procedures retention is the principal problem in flight skill retention, but that a variety of training devices can help alleviate this problem in large measure. Their findings have been generally confirmed by numerous subsequent studies in a variety of contexts.

In a similar simulator study, Hufford and Adams (1961) investigated the effects of whole- and part-task training in the learning and relearning of a complex bomb-toss maneuver. Examining retention over a 10-month interval, they found that most flight control parameters (excepting vertical speed control) remained at acceptable levels, while the forgetting of procedures was virtually complete. Also of interest is their conclusion that time-sharing skills in complex tasks are subject to decrement over time and require whole-task practice for full reinstatement. Parker and Fleishman (1960) examined the effects of amount and type of training on retention of a complex simulated radar intercept task over periods varying up to 24 months. They found virtually no decrement in the complex perceptual-motor control task over the first 14 months, and relatively little decrement even at 24 months. Two of their findings are of particular interest to us. The first is their finding that level of proficiency prior to the retention interval is closely related to amount retained after the retention interval. The second finding of interest is the high correlation (r =.80 - .98) between performance just prior to and immediately after the retention interval. While distributed practice showed some advantage over massed practice during the retraining sessions after the retention interval, the advantage was of only short duration.

Ammons et al (1958), in a very elaborate and well-controlled study, examined retention of procedural and compensatory pursuit task skills over periods of up to two years. While the tasks used were not complex, their results showed significant decrement in procedural skills, even after one month, and relatively greater retention for tracking skills. These results are consonant with the more complex task studies previously described. Of some significance, and confirmed in the results of other investigators, is the finding that, while level of performance after the retention interval

is directly a function of pre-interval level of training or performance and the length of the retention interval, the absolute amount of skill loss is a function of length of retention interval and is independent of level of original performance or training. A natural consequence of this relationship is that relative skill loss for a given interval will be greater for the lesser trained groups.

A generally consistent finding in flight skills retention research has been the finding that continuous control (tracking) skills appear to be retained better than do skills involving the execution of discrete procedures. As previously noted, Naylor and Briggs (1961) in their literature review had concluded that the integrated nature or internal organization that characterizes most perceptual-motor tasks probably is the factor that accounts for their seemingly greater retentivity than that shown by verbal or procedural tasks. Accordingly, Naylor, Briggs, and Reed (1962, 1968) examined task organization as a variable in learning and retention. Their study involved a three-dimensional tracking task and a time-shared procedural task. Results indicated that learning is more rapid for higher organization tasks, but that retention is primarily a function of level of original learning, not task organization, though an organization effect on retention was noted for low levels of training. Thus, level of original learning, which would tend to be higher for tasks of higher organization, is the factor that underlies the apparent difference in retention of control and procedural skills.

These results, as well as those of other investigators, point up the importance of measurement methodology as it relates to task difficulty, level of learning, and methods of measuring retention. For discussion of these problems, the reader is referred to Bahrick (1964, 1966) and Bilodeau (1966). The effect of method of measurement on conclusions regarding

retention can be seen in the Naylor, Briggs, and Reed (1962, 1968) research. In measuring retention of procedural skills they used three measures: (1) omissive errors; (2) commissive errors; and (3) response time. Of these, only omissive error seemed sensitive to the retention effects of the variables being studied (amount of training and task organization).

The research studies cited so far, except for that of Mengelkoch et al (1960), which involved more of a whole-task approach, have involved part-tasks or task elements in simulated settings. Another example of the part-task type of effort is the study of retention of a spaceflight skill, i.e. skill in a visual image motion compensation task, performed by Youngling, Sharpe, Ricketson, and McGee (1968). They examined effects on retention of level of training, task difficulty, and retention interval for periods of 30, 90, and 200 days. While this part-task is of rather restricted nature, their findings were generally similar to those of other investigators. They found that level of training affects level of performance after the retention interval, though there was no effect on time to re-train. Their findings on decrement as a function of time differed slightly from others, however, in that a linear relationship existed between length of retention interval and amount retained. Most investigators have leaned toward the classical negatively accelerated curve as describing the retention and forgetting functions. Another variance was their finding that the more difficult task conditions resulted in better retention performance than did the less difficult. They attribute this seeming anomaly to being a measurement problem, stating " . . . {it} may easily be an artifact of the difficulty level measurements."

Several efforts have examined retention in a whole-task setting. By far the most elaborate experiment on retention is that of Cotterman and Wood (1967). In this study of retention of spaceflight skills, four three-man crews were given five weeks of pre-mission training in the simulator for the Apollo Command Module and the Lunar Excursion Module. Training was then capped with a full 169 hour simulated lunar landing mission. Retention was tested after 4, 8, 9, and 13 weeks. While there were a number of factors that make generalization of their results to current USAF problems difficult, they found that operator performance of critical tasks fell to unacceptable levels in 8 weeks.

It is clear from results such as the preceding that NASA faces a serious problem with reference to skills retention for spaceflight involving extended time periods between original learning or practice and the later employment of the skills. The effectiveness of several methods of interim practice of various spaceflight skills was examined in an excellent series of studies by Sitterley and his associates (Sitterley and Berge (1972), Sitterley, Zaitzeff, and Berge (1972), and Sitterley (1974)). In one study, they examined retention of spaceflight skills involved in a simulated flight from lift-off to orbit insertion, while the other two efforts examined retention of skills involved in a simulated descent, approach, and visual runway landing of a vehicle of the space shuttle variety. Retention periods of one to six months were used, and effects of various rehearsal procedures and visual cues were examined. Their findings are of considerable relevance because of the similarities of task requirements of the aerodynamic type spacecraft they studied and those of current and future USAF aircraft. Degradation of control skills was moderate for

the first three months, but then increased sharply. After that point, magnitude of control errors exceeded end-of-training levels by a factor of two to three. In contrast, procedural tasks showed strong degradation after only one month. Time to execute procedures was five times as great as end-of-training value after only one month, and 17 times as great after four months. Instrument flight skills were found to degrade more rapidly than those involving far-field visual cues, a finding that is in agreement with that of Wright (1973) for a military pilot population. Sitterley et al found that both procedural and control skills could be maintained at acceptable levels over the time periods studied through fairly simple, static rehearsal techniques. This latter point finds support in the work of Prather (1973) on the effectiveness of "mental practice," and that of Dougherty, Houston, and Nicklas (1957), and numerous subsequent investigators, concerning the efficacy of simple training devices. The work of Sitterley and his associates is of considerable significance.

As has been noted, the major official attention to the skills retention area by the Air Force and the Navy in recent years, at least indirectly, has been in the form of studies of proficiency flying programs. The study of Caines and Danoff (1967), under the sponsorship of OASD(SA), examined both Navy and Air Force proficiency programs. The objective was not examination of long-term skills retention, but evaluation of proficiency levels of pilots who had engaged in then-current proficiency flying programs and the development of more effective proficiency flying programs. They examined CCTS and CRAW training grades for pilots who had been in proficiency flying status just prior to CCTS or CRAW. They found that pilots who had been in proficiency flying status performed significantly

more poorly than those who had been in full-time flying assignments, with amount of decrement being a positive function of length of proficiency flying period. Decrement was greatest for tasks involving high information volume and rate with simultaneous motor control task requirements. They concluded that proficiency flying programs were in need of improvement.

Kusewitt (1968) conducted a similar study of Navy CRT programs for the DCNO (Air). A variety of data sources were utilized, including a survey of 1,600 Naval aviators and 324 Naval flight officers. Detailed results will not be discussed here since the study was classified, but certain of the unclassified findings can be mentioned. This study, too, concluded that the CRT program needed improvement, but it was felt that the benefits to cost ratio was still 3 or 4 to 1. In examining the effects of type of aircraft used in CRT, they concluded that savings in the re-training of aviators after CRT as great as 37 hours per aviator could be realized if CRT and refresher training were in the same type of aircraft. As with Caines and Danoff (1967), Kusewitt (1968) was not concerned with long-term retention per se, but with the evaluation and improvement of CRT programs.

The United States Air Force (1969) undertook an extensive examination of its proficiency flying programs in its Saber Wings study. This effort, like the preceding one, was also classified, so it will not be discussed in detail. It involved examination of existing data such as CCTS training grades, and questionnaire responses were secured from 10,400 USAF pilots concerning their experiences and views on proficiency flying. Among the findings of interest was that clear differences in CCTS performance were found between those with aircraft flight backgrounds similar to the CCTS aircraft (i.e. fighter to fighter) and those with dissimilar backgrounds.

Also, pilots in F-4 CCTS who had operational background in other than fighter aircraft exhibited a decrement in their CCTS training performance after age 37. This age difference, while still apparent, was not so pronounced for those who had fighter background. These data suggest both age and experience as factors of concern in advanced training or retraining programs. The age effect noted for fighter CCTS (i.e. the break at age 37) does not appear until age 42 for pilots in C-130 CCTS. Predictably, most pilots favored the retention of proficiency flying programs and the use of up-to-date aircraft for proficiency flying.

The Saber Wings data are of considerable interest. The suggested importance of age, experience, and motivational factors should influence future Air Force programs, though the Saber Wings data should not be viewed as definitive. Controlled research investigations of these areas would be required for definitive answers, but there are areas that must be considered. Saber Wings was an important effort, but it must be put in context. As with the Caines and Danoff (1967) and Kusewitt (1968) studies, the orientation was more to determine the desired nature of proficiency flying programs rather than to develop data on long-term retention of flight skills.

As can be seen, the last three studies described were largly analytical and based on analyses of existing training or other data. They were not concerned with developing data directly on flight skill retention, though the data have certain implications in that regard. In view of the current problems faced by the Air Force, there is need for more research concerned with the retraining of flying skills after periods of non-flying and with non-flying methods of proficiency maintenance. The emphasis of past research on the nature of proficiency flying is less appropriate now.

Unfortunately, there is little research that has been accomplished by the services, dealing with the retraining problems. Two efforts are worthy of mention.

The first is a series of studies conducted by HumRRO for the U.S. Army. The first of these, by Wright (1969), began with an orientation similar to the studies just described, that of improving proficiency lfying programs within the existing structure. As the effort developed into a data gathering phase (Wright (1973)), the orientation shifted toward evaluating current programs for effectiveness and consideration of options, including that of non-flying followed by refresher training before moving back to a cockpit assignment. In the 1973 study, anchored scale self-ratings of flight proficiency before and after episodes of non-flying or proficiency flying were obtained from Army aviators. Respondents also provided data concerning their actual retraining experiences prior to returning to cockpit assignments after such episodes. Findings inducated that amount and nature of skill decrement were very similar for those who engaged in proficiency flying and those who did not fly at all; results for both groups indicated that basic visual flight skills remained generally acceptable for periods up to 36 months, but that instrument flight skills fell below acceptable levels for about half the pilots within 12 months. The actual amount of flight time received during retraining after the episode was only about two hours less for those who engaged in proficiency flying than for those who did not fly at all. This study raises serious question about the cost effectiveness of proficiency flying programs. The author recommends use of simulators and ground devices as a better approach.

The Wright (1973) study suffered on two points. First, actual inflight proficiency measures were not possible; it was necessary to use pilot

ratings that were made at a point in time subsequent to the episodes of concern. Second, there was no control over the retraining data in terms of content and method of retraining, levels of proficiency achieved, and other factors. Nevertheless, this represented the first systematic effort to gather data on the proficiency and retraining of a sizable military pilot population, and Wright's 1973 data present the first detailed look at the decrement function for various components of military pilot flight skills.

The next phase of this activity for the Army,(HumRRO Division No. 6 (1974)),was a small study effort that involved the gathering of detailed instrument flight performance data in a high-fidelity helicopter simulator for three pilot groups of 10 each: (1) aviators in current flying assignments; (2) aviators who had been in proficiency flying status for about a year; and (3) aviators who had been in a non-flying status for periods varying from 9 to 24 months. Following initial assessment, each was subjected to an individualized simulator retraining program designed to bring him up to the required instrument flight proficiency level. Then, after passing the standard instrument checkride in the simulator, each received aircraft training required to reach the same instrument flight criterion level inflight, and also the training required to pass a contact flightcheck. Results showed that pilots currently in flying assignments required only about half as much simulator training (6.2 hours vs. 11.4 and 11.7 hours) to reach criterion performance as did the other two groups, and that the proficiency flying and no-fly groups did not differ from each other. Required aircraft hours were very little and similar for all three groups (2.2 to 2.6 instrument hours; 1.7 to 2.6 contact hours). While this was a small-scale study, these data lend support to the contention of several other studies that proficiency flying programs, <u>as they have existed</u>, are little if any better than non-flying for maintenance of proficiency and

are probably not cost effective. Further, the data lend support to the idea that much of the retraining or proficiency maintenance requirements could be effectively accomplished in simulators.

While the HumRRO data support the contention that there is significant retention of flying skills over extended periods of non-flying, it must be recognized that the flight tasks and environment differ markedly between Army helicopters and USAF high performance aircraft. The only study of retraining requirements in the USAF context is that involving the retraining of POW returnees from Vietnam. While their retraining was not conducted as part of a study, it was possible to perform certain analyses of their retraining experiences after the fact. Data are reported in two sources, the study conducted at the USAF Air University by Armstrong, Bleymaier, Hinkel, Levins, and Shappard (1975) and in the examination of continuation vs. recurrent training conducted by Smith and Matheny (1976) for the Air Force Human Resources Laboratory. While data were potentially available on about 150 former POWs, Armstrong et al used data on 96 pilots, all of whom were retrained in the T-38 aircraft. Their interest was more oriented toward fighter pilot questions. Smith and Matheny compared data for 20 pilots who had been POW's for periods ranging from 13 to 24 months with that of 39 pilots who had been prisoners for a more extended period, 69 to 102 months. Results showed a relationship between length of non-flying episode (i.e. time as a POW) and amount of retraining time received. Armstrong et al found a correlation of $r = +.334$ between these factors, while Smith and Matheny report mean retraining flight times of 38.4 hours for the shorter time group and 45.4 hours for the longer time group. Armstrong et al report a mean retraining time of 45 hours for their subjects

with individuals varying from 12 to 95 hours. Total fighter time correlated negatively (r = -.237) with amount of retraining in the Armstrong et al analysis, while Smith and Matheny found a non-linear relationship between total flight experience and retraining time (M = 48.5 hours for pilots with 1,000 or fewer total hours; M = 35.3 hours for those with 1,001 to 2,000 total hours; and M = 41.6 for those with more than 2,000 hours).

In sum, these USAF data suggest that basic flying skills are surprisingly well retained over quite extended and most difficult non-flying episodes. Retraining to acceptable proficiency levels, Smith and Matheny (1976) conclude, could be accomplished in an average of 50 hours or less. They conclude also that abolition of continuation training could result in significant cost savings for the Air Force and should be investigated. Several points should be kept in mind with reference to these date, however. First, this was a highly special and individualized program. There is no assurance that the pilots were retrained to a common level of proficiency. In fact, it is likely that they were not, so the retraining time measures may be inappropriate. Second, the retraining program was not oriented to tactical skills in operational combat aircraft. Also, it can be argued that this is a unique group of personnel in terms of motivational factors. All in all, however, it presents a convincing demonstration, the most dramatic to date, of the high retention of flight skills over extremely long periods of time and of the relative ease with which required proficiency can be regained.

FAA Retention Studies

The preceding constitute the most significant studies of flight skill retention conducted in the military context. There are several efforts

of interest that were carried out in non-military settings. Two FAA studies and two airline efforts of interest were found. In addition, some general observations by airline personnel will be discussed. The FAA has been concerned with the extent to which skills of private and commercial pilots may degrade over time, particularly for those who may fly only periodically. Seltzer (1970) examined the effects of time on instrument flight skills (also see Seltzer and McBrayer (1971)), and Hollister, LaPointe, Oman, and Tole (1973) examined factors related to degradation of general flight skills. Both studies found decrements in skill as a function of time since pilot certification, but they were not really designed to examine proficiency retention as a function on non-flying time period. They do confirm the importance of frequency and recency of practice to pilot proficiency. There were methodological problems relating to the Seltzer study that make its interpretation difficult, but both it and the Hollister et al effort did involve acquisition of actual inflight performance data, a commendable feature. Application of these data to USAF concern is difficult because of the obvious differences in pilot skill level, population characteristics, and task complexity between the USAF situation and that of general aviation.

Airline Retention Studies

Two studies by airlines are of interest. Killian (1965) describes the experience of United Airlines in upgrading 109 second officers to pilot or first officer status. It is not possible from the data presented in that report to evaluate retention as a function of time since functioning as a pilot, even though the subjects had been in second officer status for an average of eight years. As such, they were, of course, regularly engaging in flying activities as second officers, and many were also functioning as pilots in military reserve units or in other situations during

their "non-flying" period. However, no real problems in upgrading this group (i.e. retraining them as pilots) were reported, and the author concludes that pilot skills can be retained, and even enhanced by means other than actual "stick and rudder" practice. A more recent effort by American Airlines (1976) examined the use of a modern simulator with visual system for take-off and landing requalification training for pilots who were current in another carrier aircraft, but non-current in the type being studied. No differences in flight performance subsequent to the simulator training were found as a function of length of the non-currency period. Also, no differences were found in flight performance between the simulator requalified group and a control group who were requalified in the usual manner with inflight training. This effort sheds no specific light on the subject of skill retention after periods of non-flying, but it does demonstrate the utility of the simulator in accomplishing requalification training for airline pilots.

As has been noted elsewhere in this report, part of the present survey effort involved query of air carriers concerning their experience in retraining pilots after non-flying episodes. Some nine trunk air carriers were contacted, and replies were received from six. In addition, replies were received from the Airline Pilots Association and from the Air Transport Association. The only formal studies elicited were those described above. However, the six airlines all indicate, generally, that they have no particular difficulties in retraining as pilots either second officers or pilots just joining the line who have not flown for varying periods. Their programs have in common the virtual elimination of inflight training requirements, except as mandatory under FAA regulations, through the use of

modern simulators, and the practice of individualized training to specified proficiency levels rather than to specific time requirements.

Four of the carriers shared details of the amounts of ground, simulator, and flight training they give as a function of non-flying period or time since last flying specific equipment. While these details are proprietary, they can be summarized as follows: For pilots whose non-flying period is less than one year, ground school requirements are typically 1-2 days; for those more than one year since flying, the ground school ranges 2-9 days. Simulator training range is 2 - 12 hours for those less than one year non-flying, and for those more than one year non-flying the range is 4 - 20 hours. Required flying time varies from merely the FAA-required three take-offs and landings to perhaps as much as two hours; proficiency is the determining factor.

One aspect of data supplied by one of the airlines is of interest in terms of inter-job transfer factors, similar to the DSO to navigator transition in the Tice (1973) study cited earlier. In transitioning first-officer pilots from one aircraft to another (e.g., from the 727 to the 707, or vice versa), during 1975-1976 that carrier reports average ground school time of 8-12 hours, and average time in cockpit procedures trainers (CPT) of 35-45 hours. In contrast, in upgrading second-officer flight engineers to first-officer pilot status only about 3 hours of ground school and 2-4 hours CPT time were required. However, average simulator time to proficiency was about the same for both the transition and upgrade groups (approximately 15-18 hours), as was flight time required to reach proficiency (1.0 - 2.8 hours). These data can be interpreted as demonstrating the considerable positive transfer effects between the flight engineer and pilot jobs that result in considerably reduced requirements for academic

and procedures training. Conversely, the data suggest a possibly considerable interference effect for the transitioning pilots. Comparison of the times required to reach proficiency in the simulator and in the aircraft with those found in the HumRRO (1974) study is of some interest. The times are similar, even though the flight contexts and pilot populations are quite different. In any event, the airlines do not seem to find the retraining of pilots after extended non-pilot episodes to be a significant problem.

IV. DISCUSSION AND IMPLICATION

As can be seen from the literature discussed, the state of knowledge concerning long-term retention of flying skills is not as might be desired. Research on the subject has been sporadic and not well focused. Other than the USAF program of the late 1950s and early 1960s, and perhaps the NASA program, there has been no concerted, programmatic attack on the problem that has covered both its basic and applied aspects. Over the past decade, the focus of military research and evaluation programs in this area has been primarily on the maintenance of skills through the mechanism of proficiency flying. Consequently, the subject of flight skills retention, per se, has received little attention.

In spite of this, there are certain observations and implications that can be drawn from the existing literature pertinent to current and future USAF policies in management of the rated force. While the literature presented in the preceding chapter was primarily concerned with direct studies of flight skills, it should be noted that a good portion of the state of knowledge on skills retention derives from research in non-flight settings and from research involving abstract tasks that are representative of the performatory dimensions assumed to underly flight skills, such as tracking.

In discussing the literature, the framework adopted is one aligned with Air Force operational requirements, rather than one that is academic or theoretical. Accordingly, three general categories of discussion follow: (1) general retention factors; (2) task or skill factors; and (3) retraining factors.

GENERAL RETENTION FACTORS

Level of Learning

The single most important factor in determining absolute level of performance after periods of non-practice has consistently been found to be level of learning, or skill, prior to the non-practice period. For example, Naylor and Briggs (1961), Gardlin and Sitterley (1972), Ammons et al (1958), Mengelkoch et al (1960), and Fleishman and Parker (1962) all stress this factor. The implication is that the higher the level of performance prior to the no-practice interval, the higher it will tend to be afterward. This suggests that overlearning may benefit retention. Unfortunately, the question of overlearning effects has not been investigated systematically for retention of complex skills such as flying. Many of the flight-related studies have dealt with arbitrarily established criterion levels that are far below those that characterize the professional USAF pilot. The interest here is with the higher skill levels that characterize the third, or autonomous, phase of skill acquisition discussed by Smode, Hall, and Meyer (1966). It would appear likely that intra-individual variability in performance decreases progressively during this autonomous phase, but that there are still marked inter-individual differences in performance that relate to differences in retention.

In contrast, the literature would suggest that the amount of decrement, i.e., the absolute amount forgotten, is largely independent of level of initial skill or training and is much more a function of length of the no-practice interval and other factors. A natural consequence of this relationship is that the relative amount retained (i.e., post-retention level of performance relative to pre-retention level) will be related to level of original learning. To illustrate, if individual X performs at a level of

80 proficiency units prior to the no-practice interval and 60 after the interval, he will have lost 20 units, and his relative retention can be described as 75% (i.e. 60/80 x 100). In contrast, assume that individual Y, who is less well trained, performs at a level of 60 units before the no-practice period. If he loses the same absolute amount as X, i.e., 20 units, his post-interval performance level will be 40, and his relative retention is only 67% (i.e. 40/60 x 100).

Length of Retention Interval

It is difficult to make general statements about the effects of length of retention interval that can be applied in USAF force management policies. The time factor interacts with many other factors -- e.g., type of task, personal characteristics, habit interference, etc. -- in highly specific ways. With that broad qualification, however, a few observations can be made with reference to flying skills. First, the bulk of the laboratory studies (e.g., Ammons et al (1958), Melton (1964), Hammerton (1963)); a variety of simulator studies (e.g., Mengelkoch et al (1960), Parker and Fleishman (1960), Wilson (1973), Sitterley (1974));inflight studies (Wright (1973), HumRRO (1974), Armstrong et al (1975), Smith and Matheny (1976)); and the reports of the airlines, all suggest that basic perceptual-motor skills exhibit decrement as a result of non-practice, but are retained fairly well for extended periods, and such loss as does occur is fairly easily reinstated through retraining. As will be noted in a subsequent section, there are practical differences in retention as a function of type of skill involved, but it would appear that retraining basic flying skills after periods of no flying would not be a major problem for most military pilots.

No data were found that would allow depiction, with any degree of confidence, of the quantitative relationship between time and degree of

decrement for flight skills characteristic of the USAF professional pilot. There seems to be little question that decrement does occur with no practice and that, generally, the longer the period of no practice, the greater the decrement. The classical negatively accelerated curve of forgetting has typically been assumed by most investigators to apply to flight skills, but Wright's (1973) data are perhaps the only empirical confirmation of this for overall flight performance with a military aviator population. It must be kept in mind that his data were not based on actual inflight proficiency measures, but on ratings of own proficiency. His contentions that skill degradation is rapid during the first 6-12 months of no flying and that amount of decrement after the first year is relatively slight receive some support from other research, but only indirectly. More data are needed on this point. Wright's data do suggest that, in spite of the decrements that occur, overall basic flight control skills (not instrument skills or procedural skills) remain at relatively satisfactory levels for extended periods.

Another means of attacking this point is on the basis of retraining requirements. To the extent that more retraining is required for longer non-flying episodes, it can be inferred that retention decreases with length of retention interval. Unfortunately, the data are relatively sparse in this area also, Wright's (1973) data for actual mean training time received were reported as about 5½, 7, 8, and 8 hours for non-flying episodes of ½, 1, 2, and 3 years, respectively. Estimates by these same respondents of time required to resume pilot-in-command flying duties were 14, 17½, 19 and 19 hours for the same length non-flying episodes. The subsequent HumRRO (1974) study found an average total training time to regain proficiency

(i.e. simulator time plus aircraft instrument time plus aircraft contact time) of about 17 hours for subjects who had been in a non-flying episode of about one year in length, a figure that is consonant with Wright's (1973) data. This also compares closely with the 18½ average total training time for both transition and upgrade training reported by the one airline that provided detailed data. Unfortunately, the non-flying episode status of these airline subjects cannot be determined. Finally, the two samples of USAF POW retraining data reported by Armstrong et al (1975) and Smith and Matheny (1976) show an average of 36-38 hours retraining for those who were POWs for an average of about 1½ years and 45-48 hours for those who were detained for an average of about 7 years.

The retraining times of the POWs are marked by extreme variability. For example, in the Armstrong et al (1975) data, for a group of 12 pilots whose POW period ranged from 71 to 80 months, retraining time varied from 22.9 to 79.5 hours (M = 46.5). For their total sample, the lowest retraining time was 12.6 hours for a pilot who was 11 months as a POW, while the highest retraining time was 95 hours for an 81 month POW.

It is likely that the retraining times for the POW group are inflated for a variety of reasons unrelated to proficiency, such as personal desires, building time for aeronautical designation, etc. If that be the case, one might hazard an estimate, based on all the data sources cited, that retraining of basic flying skills to satisfactory levels for USAF pilots could be accomplished in an average time of perhaps 25-30 hours after one year of no-flying and 30-40 hours after 2-3 years of no-flying. It must be recognized that these predicted average figures are based on an inadequate data base; that individual factors such as age, experience, aptitude, motivation, etc. might markedly influence the situation in specific cases;

and that the reference is to the retraining of basic flight skills only, not tactical flying skills. The general point, however, is that the retraining costs to restore basic flight proficiency would not seem excessive, even after fairly lengthy no-flying periods. Also, the research previously cited here concerning the use of simulators, as well as the sizeable simulator studies literature not cited, would indicate that much of the basic skill retraining requirements could be accomplished with high effectiveness and minimum cost in flight simulators.

There is a discontinuity in the POW data, in terms of time as POW, that resulted from the cessation of activity over North Vietnam from mid-1968 to mid-1971. This fact, as well as the relatively small numbers involved at certain data points, makes inferences about the shape of the retention or forgetting curve, as indicated by retraining hours, a rather risky procedure, but, the data that exist would not seem incompatible with the power curve function cited by Wright (1973). Whereas the Wright curve for retraining to pilot-in-command level shows about 90% of the loss occurring in the first year of non-flying and an asymptotic level of about 19 hours at 18-24 months, the POW data might suggest a slightly later approach to asymptote.

As has been stated previously, the real area of concern for the Air Force is the effect of various factors, including length of retention interval, on the retention and reqcquisition of those skills that are critical for the combat pilot. Unfortunately, no literature that deals with the decrement in combat skills as a function of non-flying time, at least of a controlled, scientific nature, were found. It is reasonable to assume that retraining times to the criterion of combat readiness will be greater than those cited for reacquiring basic aircraft proficiency; how much greater is not known. It can be argued, however, that the evidence would suggest

that combat skills decline under typical proficiency flying programs, perhaps as much as under no-flying conditions.

Habit Interference and Transfer

The relationships that exist among level of training, time, and retention are complicated in specific instances by a variety of factors. One important group of such factors is that relating to the events and activities that take place during the retention interval. Forgetting or performance decrement is generally held to result from habit or activity interference, rather than the passage of time, per se (e.g. see Naylor and Briggs (1961), Melton (1964), and Smode, Beam, and Dunlap (1959)). Most such interference would result from activities during the retention interval. Adams (1967) in his book, Human Memory, states:

> "For all its problems, it {the intefrerence theory} is the best theory of forgetting that we have, and the evidence is almost solely derived from verbal behavior and recall. The significance of interference theory for nonverbal response classes and for recognition is mostly untested and vague. This is a grievous deficit because an overriding issue for memory is whether one set of lawful principles, or more than one, is required to explain forgetting. No strong resolution of this issue will take place until the laws of forgetting are tried in a multitude of situations and for a variety of response classes." (pp. 305-306.)

While the research situation, as described in the Adams quotation, is far from satisfactory, some efforts have been made to examine such factors. The research and evaluation efforts on proficiency flying, for example, have provided suggestions, at least, concerning habit interference. A number of the evaluation studies, such as Kusewitt (1968), Snow (1965), and the USAF (1969) Saber Wings study, have suggested that type of aircraft flown during proficiency flying periods has an effect on skill retention and later retraining performance. Wright (1973), in fact, found that pilots who had performed their proficiency flying in light aircraft during non-flying

assignments, and were then retrained in a more complex operational utility aircraft, received an average of 1.2 hours more retraining instruction than did pilots who had not flown at all during non-flying assignments. Kusewitt (1968) states that refresher training savings as great as 37 hours per Naval aviator are possible when proficiency flying and refresher training are done in the same model aircraft.

Results such as these can be viewed in terms of habit interference or in a more positive framework in terms of transfer principles. However, results such as the USAF (1959) Saber Wings findind of substantial effects on CCTS training grades of similarity or dissimilarity of recent experience aircraft type with the CCTS aircraft type, whether viewed in terms of transfer or in terms of habit interference, are factors of concern. Further, when the interaction of these factors with others such as age are considered, the complexity of the force management problem is compounded.

Rehearsal Effects

A more useful point of view, perhaps, relates to means of minimizing decrement during periods of non-flying and of maximizing performance or relearning after such periods. A variety of researchers have examined rehearsal effects and distribution of practice as means of minimizing decrement. Their results have generally shown rehearsal to be beneficial, even when involving fairly simple representations of task elements. For example, Sitterley's (1974) finding that distributed rehearsal of a static (i.e. non-hands on) practice task with static visual cues could sustain satisfactorily for at least six months a fairly complicated spacecraft approach and landing skill demonstrates the power of rehearsal. One of the air carriers contacted reported interest in using the Sitterley technique in retraining airline pilots.

The use of training devices of various sorts to maintain or retrain skills is well established (e.g., see Mengelkoch, Adams, and Gainer (1960), Adans and Hufford (1962), HumRRO (1974)) and represents a type of rehearsal. Such devices vary in complexity and cost, so their selection and use should be done in deliberate fashion to achieve specific goals. Of course, proficiency flying itself can also be viewed as an interim rehearsal technique, and its productiveness will be subject to the same general rules that guide the productiveness of less elaborate techniques. In view of the apparent effectiveness of certain fairly simple rehearsal techniques, and the apparent ineffectiveness of many proficiency flying programs, questions arise as to the reasons for this discrepancy. The answer likely lies in the fact that the "simple" techniques are carefully designed and controlled training experiences, targeted on critical task elements or dimensions. In contrast, proficiency flying programs have typically not been so carefully designed, controlled, and targeted; their major goal seemingly has been that of simply putting the pilot in the air, apparently a result not sufficient for maintaining proficiency in operational tasks.

TASK/SKILL FACTORS

Control and Procedural Tasks

The literature suggests that there is no fundamental difference between continuous control tasks and procedural tasks, as far as learning and retention are concerned, if task organization is taken into account. Despite this, in practice a variety of investigators have found procedural tasks to exhibit more rapid and greater relative decrement than do continuous control tasks. For example, Mengelkoch et al (1960) found flight procedural skill decrement after only four months that was both statistically and practically significant. Hufford and Adams (1961) found forgetting of

certain flight procedures to be virtually complete after 10 months. Sitterley and his associates (1972a, 1972b, 1974) found sharp decrement in procedural skills after only one month with a further sharp degradation after three months. Sitterley and Berge (1972) state:

> "The results reflected a fundamental difference in skill degradation between the procedure and continuous control tasks. . . . The magnitude of the degradation was clearly unacceptable at the shortest interval for the procedure task, and at a level which was not found for the continuous control task until 3 months without practice. At 3 to 4 months, when both tasks showed the sharply increased loss in performance, the relative degradation magnitude of the procedure task was five times greater than the continuous control task." (p. 65)

As stated, most researchers would agree that the observed differences in retention of procedural and control tasks are related to the task organization factor. However, a characteristic of the procedural tasks peculiar to flying seems to be their lack of inherent organization. Consequently, they do exhibit marked and rapid decline, empirically, a factor that must be taken into account in developing skill maintenance programs. Fortunately, the research data also indicate that procedural skills can be maintained or retrained relatively easily with fairly simple means. Their integration with non-procedural aspects of the flight task in a time-sharing situation still requires some whole-task practice, however,

In contrast, the literature on continuous control tasks indicates that retention is generally high, even for extended time periods. Such tasks typically have a high degree of internal organization and provide continuous, immediate, and clear-cut feedback or indications of response correctness to the performer. However, it should be noted that much of the data available deals with tasks that are considerably less complex than those involved in the operation of USAF combat aircraft, and the levels of training or skill represented in many of the studies are much lower than those

of the professional USAF pilot. Pertinent to this point are the results of Hammerton (1963) using a difficult second-order tracking task. He found significant decrement in control skills after a six month period. Similarly, the results of Sitterley et al (1972a, 1972b), using a complex spaceflight task, showed an increase in control skill degradation after three months, with control error rates being 2-3 times as great as at the end of training. These results suggest that the "sharp edge" of control performance shown by high skill pilots may decline fairly quickly over time, even though basic control skills (which must be considered highly overlearned for the experienced pilot) may remain relatively intact for extended periods.

Instrument and Contact Tasks

Several investigators have found a differential in decrement functions for instrument flight tasks and contact flight tasks.[1/] Both Wright (1973) and Sitterley, Zaitzeff, and Berge (1972) report decrements in instrument skills of greater practical concern than was the case for visual flight skills. One likely factor in the relatively greater degradation of instrument control skills is the typically heavy procedural task loading of the instrument flight tasks. While Sitterley et al (1972) were expecting greater degradation for the visual flight tasks, their findings showed degradation to be almost twice as great for the instrument flight tasks as for the contact tasks. They suggest this may be due to the relatively higher task loading that characterized the instrument portion of their flights.

Information Processing Tasks

As discussed elsewhere in this report, one conception of the pilot's

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[1/] The distinction is between those flight tasks or situations in which principal cues for the pilot are provided by instruments within the cockpit, as contrasted with those situations in which cues are provided, at least in part, by visual contact with the extra-cockpit environment.

task, particularly at the advanced skill levels of the combat pilot, is that it is principally an information processing task. Undoubtedly, there is merit to examining the pilot's job from this point of view. It may well be that it is his skill in handling large volumes of complex information rapidly and correctly that characterizes the effective, skilled professional combat pilot. Assuming that this skill is largely acquired through the long process of training and operational flying that characterizes the autonomous skill phase (Smode, Hall, and Meyer (1966)), the question of its rate and amount of degradation during non-flying periods is of considerable interest to the Air Force. Unfortunately, no literature dealing with retention of this skill or function has been located. Tools for its study, involving the concept of residual attention and techniques such as use of secondary tasks, are available, and such research seems warranted. Decision making skill can be viewed in much the same way in terms of its potential importance to pilot viability and force management policies, but lack of data, unfortunately, prevents any meaningful conclusions in this area.

Other Task Factors

There are a number of other task dimensions or aspects of the operational task environment of potential concern to the Air Force, but about which little data or firm conclusions concerning retention exist. For example, little has been published concerning retention of specific tactical skills such as weapon employment, target acquisition, and the like. Communication skills are critical to certain situations, but no studies of their retention were uncovered.

An aspect that is potentially extremely important to the area of retention and force management relates to performance under conditions of stress.

Relatively little is known about the development by the pilot of the ability to perform effectively and reliably under conditions of stress, particularly the stress of combat. While it is probable that a portion, perhaps a major portion, of the pilot's stress tolerance is independent of his flight training and flight experiences, it is likely that it is also significantly affected by his flight experiences. The nature of decrement in this ability to perform under stress that might result from non-flying episodes is not known. Nor are there data concerning the re-acquisition or rebuilding of this ability or factor after a non-flying period. This is a significant area of research need.

Another aspect of flight skills on which the retention literature is silent relates to the matter of task and ability structure, as discussed with reference to the work of Hulin and Alvares (1971a, b, and c). While the theoretical aspects of these positions are beyond the scope of the present discussion, it may well be that a real understanding of this aspect of pilot skills and their retention holds the key to effective maintenance, retraining, and management of pilot skills. In less complex terms, these factors may relate to changes in control or task performance strategies that take place as a function of training that allows certain performatory routines to become fully or semi-autonomous. The stability of these higher level task performance strategies over periods of non-practice and the extent to which they can be maintained or reinstated are not known.

RETRAINING FACTORS

Use of Devices

It is clear that a variety of procedures and techniques are available for the accomplishment of flight skills retraining requirements. There would seem to be little question concerning the efficacy of using training

devices and simulators for the maintenance and retraining of a variety of flight skills. Results such as those of HumRRO (1974) and of the airlines would indicate that all or virtually all of the training required to reinstate basic flight control and procedural skills can be accomplished in modern flight simulators. Even for certain visual flight requirements, including takeoff and landing, the simulator has been shown to be adequate.

At a simpler level, the use of a variety of part-task or lower fidelity devices has been shown to be cost effective. Much can be accomplished in the maintenance or retraining of many flight skills with such devices, particularly in the area of procedures, but the previous observation concerning the criticality of targeting training objectives and controlling the training situation should be noted.

It must be recognized, though, that much less is known about the effectiveness of simulation for the acquisition, maintenance, or retraining of the "sharp edge" combat skills. Current Air Force programs such as the SAAC (Simulator for Air-to-Air Combat) will shed light on this area. While there is no reason to believe that simulation cannot make a substantial contribution to the development of the higher order flight skills, much needs to be done to determine the nature and extent of such contribution. However, even while seeking the answer to such questions, USAF force management policies should take advantage of the already demonstrated great potential devices hold for proficiency maintenance and retraining programs.

Nature of Training

There are several general conclusions that can be drawn from the literature cited and the general training literature pertinent to the nature of USAF proficiency maintenance or reinstatement programs. As was noted in the section on Retention Factors, the required length of retraining programs is highly conjectural on the basis of what is known, but, the literature does clearly support: (1) careful specification of program objectives;

(2) deliberate design of training programs to accomplish the objectives; (3) adequate methods of measurement and quality control; (4) use of individualized, proficiency-paced training techniques; and (5) use of simulators and training devices as cost effective means of accomplishing training requirements.

Individual Factors in Retraining

There are many factors relating to the characteristics of individual pilots or of various sub-populations of pilots that are of potential concern to the Air Force in its force management policies. The concept of the "unviable pilot," discussed earlier, is obviously based on the presumption of such factors. Of course, manpower management policies can quickly become unmanageable and meaningless if they try to take into account a large number of highly individualistic factors. Understandably, management policies are based on factors of known relationship to program objectives, factors that can be easily identified (preferably quantified) for substantial numbers of personnel.

One such factor that has received some attention, though not enough, is that of pilot age and its relation to performance. The psychological literature indicates that there is a general decline in learning efficiency and flexibility that begins perhaps in the late teen years and continues on into old age. In practice, this effect is offset to varying degrees by the accrued benefits of experience. A number of researchers, for example, support the idea that one can "learn how to learn" and thereby make his learning performance more efficient over time. Likely, this is an aspect of the third (autonomous) phase of pilot skill acquisition. While there are obvious benefits that are concomitant with increasing age and experience, there is general agreement that at some point there is a decline

in pilot ability to perform effectively under the physiological and psychological stresses that characterize combat flying.

Data to allow a more precise articulation of this last contention are sparse, especially as they relate to retention and retraining. The Saber Wings (USAF (1969)) data suggest the existence of age-related differences in training efficiency as a function of aircraft and task factors. An example is the finding that fighter CCTS training performance shows a decline beginning at age 37, but this decline does not manifest itself until age 42 among those undergoing C-130 CCTS. One hypothesis that might be advanced to explain this finding has to do with the rate at which things happen in flight and the complexity of the stimulus situation. Stated differently, it has to do with information processing. Caines and Danoff's (1967) observation that a major area of deficiency among CRT pilots was that relating to time-shared tasks with high information volume and rate also is supportive of the importance of the information processing skill. From such results, it would seem that decline in this functional ability and its relation to specific flight task requirements should be an area of major concern to USAF management policies with reference to proficiency maintenance and retraining. While the Saber Wings (1969) data are perhaps the best available and do provide some basis for policy development, a better data base is warranted.

The relationship between age and accident experience has received considerable attention. However, as noted by many researchers (e.g., Zeller (1962), Zeller and Burke (1967), Copp (1971)) the relationship is not a simple one. The manner in which skills retention, age, experience factors, and accident experience might be used in developing force management policies is complex. Since no one would advocate operational flying

after extended layoffs without controlled retraining, the problem for the USAF is to identify the underlying age-related factors relevant to accident experience (e.g., information processing, procedures skills, perceptual capabilities) that can be operant in retraining programs and to control them. Control might take the form of specific training prescription or preventive procedures, or it might be instituted through manpower management policies that would exclude certain individuals or population sub-groups from entry into retraining programs. The present state of knowledge is inadequate to this need, though.

Other types of individual factors can be of importance. Studies such as Kusewitt (1968), Saber Wings (USAF (1969)), and Wright (1973) indicate some of the problems concerning the relationship between retraining aircraft type and aircraft type flown earlier. While such difficulties can be attributed in part to habit interference and negative transfer, interpretation of such data is confounded by differences in task difficulty peculiar to specific aircraft. The general literature would suggest that across-type transitions from more difficult to less difficult aircraft can be accomplished more readily than in the reverse direction. This is an area of possible concern in force management.

Another factor of considerable potential concern in the management of the rated force and the unviable pilot relates to the degree to which retraining and later performance can be predicted for individuals or groups of indivuduals. The extremely high correlations found by Parker and Fleishman (1960) over periods of up to 24 months in pre- and post-retention interval performance suggest a stability of relative performance level that could be useful. While controlled data studies of pilot performance predictability over periods of non-flying were not found, the research of Miller (1974)

with reference to means of optimizing pilot assignment and the multivariate performance predictor research of the Navy[1/] and the Army[2/] suggest the possibility of effective means of predicting post-retention interval performance. A thought-provoking recent paper by Christal[3/] suggests that aptitude tests may be useful not only for predicting speed of skill acquisition in original training, but in predicting rate of skill decay and rate of skill reacquisition. If so, aptitude data could be brought to bear, along with a variety of other predictors, to identify those less likely to benefit from retraining or less likely to perform effectively after retraining. This is really the crux of the unviable pilot problem. If such pilots exist in numbers sufficient to be of management concern, and if they can be reliably identified through predictor relationships, then force management policies can be formulated to maximize benefits to the Air Force. Care must be taken, though, to insure that the management system is not structured to make the unviable pilot a self-fulfilling prophecy.

A final area of individual factors worthy of comment is the effect of non-flying periods on pilot motivation. Concern on this score is expressed in the examination of Navy proficiency flying programs by Caines and Danoff

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[1/] Schoenberger, R.W., Wherry, R.J., and Berkshire, J.R. Predicting Success in Aviation Training. Research Report No. 7, U.S. Naval School of Aviation Medicine, Pensacola, FL, 1967.

[2/] Dees, J.W. and Dufilho, L.P. Multivariate Extrapolation of Training Performance. HumRRO Technical Report 75-16, Human Resources Research Organization, Alexandria, VA, 1975.

[3/] Christal, R.E. What is the Value of Aptitude Tests? Paper presented at the 18th Annual Conference of the Military Testing Association, Gulf Shores, AL, 19 October 1976.

(1967), of Army programs in the Wright (1969) review study, and of Air Force programs in the USAF (1969) Saber Wings study. Certainly, pilot values and motivation patterns change over time. It is possible that some pilots cannot tolerate a hiatus in their flying experience and sustain the degree of concentration and dedicated professional effort required of the USAF professional combat pilot. Others may be able to sustain their performance quite adequately after a non-flying period. Existing data do not provide a basis for informed action on this point, and research exploration should be undertaken.

V. CONCLUSIONS

Based on the preceding discussions, several general conclusions can be drawn. While it is obvious that the drawing of conclusions from the rather sparse behavioral science data that exist is a hazardous undertaking, it is equally obvious that the Air Force must develop and implement force management policies and initiate programs regardless of the state of behavioral science knowledge concerning long-term flight skill retention. It is also clear that behavioral considerations are only one of a number of factors that policy makers must consider.

Whereas past Air Force concern has been largely with the question of how best to maintain flying skills through proficiency flying programs, concern now must also be with the question of how to retrain flying skills after periods of non-flying. Whichever aspect is predominant in future Air Force programs -- skills maintenance or skills retraining -- the behavioral science findings on long-term flight skills retention are pertinent. In view of the shift[1/] toward the practice of no-flying followed by possible retraining that has resulted from recent fiscal and fuel resource considerations, conclusions concerning the retraining of flight skills after non-cockpit assignments are of increasing interest.

The conclusions are presented under three headings: (1) those relating to general aspects of flight skills maintenance/retraining questions; (2) those relating to aspects of Air Force manpower management policies for the rated supplement; and (3) those relating to research needs relevant to the preceding categories.

1/ Reports as of this writing indicate that the U.S. Navy has abolished proficiency flying programs for Navy and Marine Corps aviators, effective 1 October, 1976.

FLIGHT SKILLS MAINTENANCE/RETRAINING

1. Basic flight control skills are retained well over extended periods of non-flying, and such decrement as occurs can be remedied through appropriate retraining programs. Principal areas of concern are instrument and procedures skills.

2. The extent and manner of degradation of tactical flight skills and higher order flight skills over non-flying periods are largely unknown. While it is likely that such skills can be reinstated satisfactorily through retraining for most pilots, the cost and nature of such retraining and the proportion of Air Force pilots for whom such retraining will be cost effective are not known.

3. If a policy of non-flying followed by retraining is adopted for some or all Air Force rated supplement pilots, there are various actions that can be taken during the non-flying period to increase level of skills retention and, consequently, to decrease retraining costs. Such actions can also increase the benefits of proficiency flying programs if that alternative is chosen.

4. Both proficiency maintenance and retraining programs should be designed around specific behavioral objectives. They should be based on modern training technology, and the behavioral emphasis should be reflected in proficiency measurement systems that provide assurance that proficiency and force readiness goals have been attained.

5. Various training devices can be used with high cost effectiveness in flight skills maintenance and retraining programs. These vary from quite simple devices to complex flight and weapons systems simulators. Virtually all, if not all, of transition, proficiency maintenance, and

retraining requirements for basic flight skills can be met this way. While such devices can undoubtedly be used to advantage with reference to acquisition, maintenance, and retraining of tactical and higher order flight skills, considerably less is known about such use of devices than is known about their use for basic flight skills.

6. The concept of the "unviable pilot" receives some support from the research literature. There are indications of relationships among skill maintenance, retention, retraining, and tactical performance factors, on the one hand, and pilot population characteristics, on the other, of such nature that the unviable pilots may be potentially identifiable in a fashion that will allow their effective management. Relevant population factors of potential concern include pre-retention episode level of performance, age, amount and type of experience, previous training and operational performance indices, aptitude measures, and motivational factors. While the behavioral science and statistical methodologies exist that would allow determination of the validity of the unviable pilot concept and the feasibility of an operational system for identifying such pilots if they exist, the present state of knowledge of pilot characteristics -- i.e. the data base -- is inadequate for establishment of a management program involving such a system.

MANAGEMENT OF THE RATED FORCE

1. Effective management of the rated force with reference to the maintenance and retraining of flying skills requires behavioral science input. The interfacing between behavioral factors and manpower and force management models needs clear articulation for an effective behavioral science input. Force and manpower management variables such as age, rank structure, force makeup, contingency plans, operational effectiveness

requirements, future missions and equipment, and the like must be specified in terms of their behavioral requirements and implications if proper behavioral data are to be developed and inputs provided policy planners in timely fashion.

2. There is need of a management information system that provides continuing feedback on the effectiveness of skills acquisition, maintenance, and retraining programs. It should provide information in terms that permit use in management models, but a prime requirement is that such indices be based on sound methodologies of pilot proficiency measurement that are relevant to both basic flying skill requirements and higher level and tactical mission skill requirements.

RESEARCH NEEDS

There are a number of areas relating to flight skill retention in which both basic and applied research are required to meet the needs for effective management of the rated force. These include:

1. Nature of higher level pilot skills. The present review reveals that little research has been done on the nature, development, maintenance, and retraining of the higher level flight skills characteristic of the professional USAF pilot. Areas such as ability/skill changes over time and experience, information processing concepts, multi-task residual attention capabilities, and learning and performatory strategies for higher skill levels appear as promising areas of investigation.

2. Nature of flight skills degradation. Some data exist on the nature of decrement functions for basic pilot skills. However, the data base needs expanding to cover more adequately the pilot populations, skills, and retention intervals of concern. Very little has been done concerning decrement functions for higher level skills such as described in paragraph 1.

It is the degradation of these higher level skills as a function of time and other factors that is most in need of specification for effective force management programs.

3. Factors in acquisition maintenance, and retraining of higher level pilot skills. The state of knowledge concerning the acquisition, maintenance, and retraining of basic flying skills is generally adequate for the development and implementation of more cost effective programs. However, this is not the case with reference to higher level pilot skills. Paralleling the needs described in paragraphs 1 and 2 is the need for development of principles and understanding of effective training programs for higher order flight and tactical skills. While there is no reason to expect the principles underlying effective training to differ fundamentally for basic and higher skills, though such might be the case, until the nature of these higher skills is defined adequately and specific objectives for their training established, it will not be possible to develop acquisition, maintenance, and retraining programs of maximum effectiveness. One particular aspect of concern is the need for advancing the technology of design and use of simulation for the training of higher level pilot skills. This implies attention to tactical gaming and engagement simulation techniques as well as those techniques related to operation of the aircraft and its systems.

4. Overlearning and higher level pilot skills. The literature consistently shows level of retention to be related to level of original learning. The interaction of overlearning of basic skills with development of higher level pilot skills needs examination, as does the relationship of overlearning to skills maintenance, retention, and retraining. If overlearning of certain performatory routines is necessary to their becoming semi-autonomous in order to allow the development of higher skills,

the questions of which skills warrant overlearning (i.e. repeated practice), how much overlearning, when in the pilot's career and on what schedule, and how to measure overlearning effects are of critical concern.

5. Performance under stress. It is clear that the USAF pilot must be able to perform reliably and effectively under conditions of severe stress. The manner in which this capability develops and the extent to which it changes as a function of conditions such as non-flying or proficiency flying episodes, age, and career, experience, and personal factors are not known. Because of the criticality of the stress factor to mission performance, force management policies must be based on sound knowledge in this area. Adequate mission performance requires more than just the requisite mechanical skills. Resistance to the disorganizing effects of stress must be sufficient to permit the mechanical skills to operate in effective, integrated fashion. Research is required to this end.

6. Identification of the viable pilot. There are many ways in which pilot effectiveness and viability may be defined. In the present context, the viable pilot may be described as the pilot who can undergo a period of non-flying or proficiency flying and return to cocipit duties as a satisfactory performer. Further, the cost for skills maintenance or retraining must be affordable to the Air Force in terms of benefits produced for resources expended. The viable pilot, then, retains over such periods his ability to learn, to bring skills back to required operational levels (if, in fact, his skills degrade in the same way as the less effective pilot's), and most importantly, subsequently to perform effectively in the mission environment. The opposite of the effective pilot in this context is the "unviable pilot." Little real data exist on the characteristics of these

two groups, if there are two discriminable groups. Research is needed to determine if they do exist and, if so, to develop means for their discrimination. If retention performance (in the sense described here) can be predicted with required accuracies, a manpower management system could be developed to maximize force readiness benefits.

7. Measurement. The research literature reveals little on effective measurement techniques for higher level pilot skills. Progress in this area is required for adequate pursuit of research on retention of higher pilot skills and for the development of effective force management procedures. One particular aspect is the need for adequate definition of and means for measuring pilot combat readiness.

8. Pilot Motivation. Some data exist relating to motivational aspects of various programs of pilot skill management. Current data are inadequate to the needs of a sound manpower management program as they relate to the interaction of various management alternatives and pilot career and performance motivation. Indices of the potential importance of this area to rated force management are sufficient to warrant thorough investigation of these factors.

9. Pre- and post-episode evaluation. Since pilots currently enter and leave the rated supplement regularly and in substantial numbers, a program should be instituted to examine systematically and scientifically their pre- and post-episode flight performance capabilities. Such evaluations, which might be done for all pilots concerned or, more likely, on a sampling basis initially, would allow development of the data base needed to answer many of the questions posed. It need not be a high cost program and could be a routine procedural part of entry to and exit from the rated

supplement force. Obviously, the nature of such evaluations would require careful thought and planning, but an evaluation program would be implementable within a fairly short time frame.

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APPENDIX

LISTING OF

LIBRARIES, AGENCIES, AND INDIVIDUALS CONSULTED

LIBRARIES, AGENCIES, AND INDIVIDUALS CONSULTED

A. LIBRARIES

1. HumRRO Central Division (Pensacola, FL)
2. HumRRO Eastern Division (Alexandria, VA)
3. HumRRO Western Division (Carmel, CA)
4. USAF Air University (Maxwell AFB, AL)
5. Air Force Human Resources Laboratory (FT) (Williams AFB, AZ)
6. Air Force Office of Scientific Research (Bolling AFB, Washington, DC)
7. Naval Aeromedical Research Institute (Pensacola NAS, FL)
8. Naval Training Equipment Center (Orlando, FL)
9. US Army Aeromedical Research Laboratory (Fort Rucker, AL)
10. University of West Florida (Pensacola, FL)
11. University of Illinois Aviation Research Laboratory (Savoy, IL)

B. AGENCIES AND INDIVIDUALS

1. Office, Director of Defense Research and Engineering (Life Sciences)
   COL Henry L. Taylor
2. Air Force Human Resources Laboratory
   COL Dan D. Fulghum
   Dr. Edward E. Eddowes
   Dr. William V. Hagin
   Mr. James F. Smith
3. Air Force Office of Scientific Research
   Dr. Alfred R. Fregly
   Dr. Charles E. Hutchinson
4. Naval Aeromedical Research Laboratory
   CDR Thomas Gallagher
5. Naval Training Equipment Center (Human Factors Laboratory)
   Mr. James Duva
6. US Navy Training Analysis and Evaluation Group
   Dr. Alfred F. Smode
7. Naval Safety Center
   Dr. Robert A. Alkov
8. Air Force Inspection and Safety Center
   Dr. Anchard F. Zeller
9. Naval Postgraduate School
   Dr. Gary Poock
10. Center for Prisoner of War Studies, Naval Health Research Center
    LCDR Charles W. Hutchins
11. US Army Research Institute, Fort Rucker Field Unit
    Mr. Charles M. Gainer
12. US Army Aeromedical Research Laboratory
    COL Robert Bailey
    Dr. Robert H. Wright
13. US Army Agency for Aviation Safety
    Mr. D. S. Ricketson

14. RAF Institute of Aviation Medicine
    Dr. John W. Chappelow
    Dr. John Gundry
15. RAF, Headquarters, Training Command
    Dr. John M. Rolfe
16. Oxford (England) Air Training School
    Mr. R. P. Terry
17. Swedish Air Force Staff
    Dr. Maud Tuanderz
18. Swedish Royal Institute of Technology (Flying Simulators Laboratory)
    Mr. Svante Skans
19. NASA, Man-Machine Integration Branch
    Dr. John Lauber
20. FAA, Civil Aeromedical Research Institute
    Dr. W. Dean Chiles
21. University of Illinois
    Institute of Aviation
        Mr. Ralph Flexman
    Aviation Research Laboratory
        Dr. Charles Hopkins
        Dr. Stanley Roscoe
    Department of Psychology
        Dr. Jack A. Adams
22. The Ohio State University
    Center for Vocational Education
        Dr. Harry L. Ammerman
    Department of Psychology
        Dr. Milton D. Hakel
23. Parks College of St. Louis University
    Mr. Harold Wood
24. Embry-Riddle Aeronautical University
    Dr. Frank G. Forrest
25. Miami-Dade Community College
    Department of Institutional Research
        Dr. Gustave G. Wenzel
    Department of Aviation
        Mr. Robert M. Kane
        Mr. Neal P. Benson, Jr.
26. American Airlines
    Dr. Robert Houston
    Dr. Dave Killian
    Mr. Jack Mansfield
27. Braniff International Air Lines
    Mr. Marion S. Griffith
28. Delta Air Lines
    Mr. C. A. Smith
29. Eastern Air Lines
    Mr. E.P. Rordam
20. National Airlines
    Mr. G. M. Watkins
21. Trans World Airlines
    Mr. D. R. Alexander
32. Air Line Pilots Association, Research Department
    Mr. Michael E. Sparrough
33. Air Transport Association
    Mr. J. Roger Fleming
34. Life Sciences, Inc.
    Dr. W. Guy Matheny